Chapter I

INTRODUCTION: SCOPE OF THE REPORT

1.1 The Remit

We feel that it is hardly necessary nowadays to consider whether mathematics and science should find a place in a balanced or liberal education. It may be sufficient to quote from the Policy Statement of the body now known as the Association for Science Education. 'The effects of science on human life and thought have become so great, and are potentially so much greater, that those who have no understanding of them, and of the science which produced them, cannot be considered properly educated or truly cultured and therefore are unable to participate fully in the life of their time . . . Science should be recognised and taught as a major human activity which explores the realm of human experience . . . It follows that schools have the duty of presenting science as part of our cultural and scientific heritage to be taught in harmony with, not in opposition to, the various arts subjects which alone have hitherto been called humanities.'*

The world we live in has been transformed socially, and sometimes even physically as well, by the application of science in modern technology. Whether for good or ill, society today is circumscribed by the results of scientific thought. Thus, to provide some knowledge of science, of scientific method, of the language of science as well as of some general ideas of the scope and depth of its application in the great technological achievements of the modern world, should be one of the aims of a balanced educational system for everyone.

It is generally accepted that the scientist and the technologist have an important part to play in modern society. The aim of education, however, is not merely to train scientific specialists—or indeed specialists in anything else. For those who wish to specialise in some scientific field, the educational system should provide the necessary facilities. Equally important is the provision of facilities for the non-specialist in science to acquire some basic scientific background for him to understand and play his part in modern technological society. At the same time, in the education of the future science specialist a due place must be assigned to the arts and the humanities.

We felt therefore that our aim should be to consider, not whether science and mathematics should play a part in a balanced educational system, but rather to what extent and at what stages should mathematics and science be included in the field of study. As a necessary corollary, it is also important to consider whether the teaching in these fields is being adequately served by the resources—human as well as material—that are available today or are likely to be available in the near future.

**Science and Education*. A Policy Statement, 1961, p. 5. (London: John Murray for The Science Masters' Association and Association of Women Science Teachers).

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1.2 Method of Treatment

In our Report we endeavour first to consider what is involved in a balanced or liberal education and then to study the place of mathematics and science in the present educational system in Wales. Consideration of the position in the schools, both primary and secondary, naturally leads us to consider aspects of the position in teacher training colleges, technical colleges and universities, from the point of view of the supply of teachers with the required scientific background and qualifications. We then consider the demands of Wales, industrially, commercially and professionally, on the educational system. Finally, we attempt to assess whether the present place of mathematics and science is such as to meet these demands and, at the same time, be consistent with the idea of a liberal education. Accordingly, this Report falls into parts broadly corresponding to these different aspects of the study.

In the study itself the Council invited evidence from industrialists, scientists, educationists, teachers at all stages from primary school to university, and H.M. Inspectors of Schools, as well as from various professional associations and institutions. We also found it necessary to make our own investigations, and issued questionnaires to all secondary schools and training colleges in Wales to obtain information covering present teachers of mathematics, science subjects and the balance of studies in the schools. In our work we naturally took into account such published findings of other Committees or Councils as have a bearing on our remit.

We have held a large number of formal meetings, received from individuals or organisations written evidence covering a comprehensive range, and we have held a number of informal meetings. We also arranged a number of interviews to obtain personal opinions on broad matters which were relevant to our deliberations. We visited primary schools in North and South Wales to observe different methods of teaching mathematics—both traditional and modern, and visited an industrial undertaking to discuss its apprentice scheme and its recruitment from secondary schools.

The Report is concluded by a list of recommendations and conclusions to which we have been led by the considerations given in some detail in the various chapters. Inevitably, we encountered questions and problems which themselves might well form subjects for further consideration. On other matters, such as the contents of syllabuses in the various science subjects, we did not feel competent as a Council to make other than the most general observations; there are professional panels for dealing with these questions in detail.

There is one matter, however, which it is perhaps advisable to explain at the outset. Our terms of reference are naturally limited to the Welsh scene. Where considerations of the demands on the Welsh education system are concerned they must be limited to the position in Wales itself. However, many of those employed in the educational and industrial system in Wales come from outside Wales. At the same time, many of those educated in Wales find employment elsewhere. Many of the Welsh people themselves are educated outside the country, while many from outside Wales are being educated here. This interchange does not affect the position in the United Kingdom as a whole, and is, indeed, highly desirable; nevertheless, it does not make it easy to obtain exact figures. We have considered that progress could best be made by assuming that Wales is a viable unit for the purpose of making estimates, for example, regarding the numbers and movements of school leavers into industry or commerce, or the numbers of actual University graduations. As long as this is realised in considering the various data presented, it is felt that the danger of misinterpretation will be reduced.

1.3 Education in an Industrial Society

An educational system is part of the wider social scene and must reflect the needs, trends and general standards of that society. Clearly, the industrial revolution of the early nineteenth century had profound repercussions on the educational system of this country—the establishment and growth of mechanics institutes, technical colleges and universities with a technical and scientific bias were all a direct consequence of this.

Since World War II we have seen the effects of a second industrial revolution, and this has been nowhere more evident than in Wales. There has been a swing from traditional (or 'muscle-based') production units to science-based industry and automation using modern scientific control techniques. This change will have its effect on the educational system. The more sophisticated industrial techniques of today require better educated recruits into industry at all levels than those recruited even before World War II. It is now accepted that research and development must lie at the very root of a modern industrial economy. To ensure effective development not only is the provision of an adequate number of good scientists essential for the basic research but it is equally important that they should be associated with and supported by the appropriate number of technologists, technicians and craftsmen; this point has, perhaps, not always been fully appreciated. For the development of the results of research the role of the technician is crucial.

A large proportion of those who pass through the educational system require vocational training, and such education for industry must be considered in the light of the changing industrial pattern in Wales today. The change-over from the traditional type of numerous small units in the heavy industries of coal, iron and steel to the modern industries, many of them concentrated in large units, is bringing about a change in the type of person employed, particularly at the apprentice and craftsman level. Modern techniques require not only scientists and technologists of graduate level but also operatives with an up-to-date technical educational background.

Furthermore, scientific and technological developments are proceeding at a rate which is already higher than that at any previous time in history, and there appears to be an ever-growing need for the training of scientists and engineers. This fact places a great responsibility on the educational system. Clearly, those recruited into industry today must be able to deal with the developments of the future, not merely the situation as it is at present.

In this changing industrial pattern the need for a knowledge of science is not confined to those who are going to do specialised work. This fact emphasises the importance of a balanced education, particularly in the sixth forms of our grammar schools where the work tends to become unduly specialised, whether in arts or in science. The increasing insistence by industry on the desirability of a broader education coincides with the rapid growth of science which is leading to more specialisation in honours degree courses. This poses a difficult problem.

Further, the range of executive responsibilities in modern industry is becoming increasingly complex, and many industrialists have expressed the view that higher education should go some way to prepare the potential recruit for these responsibilities. It is possible, however, that society may develop along lines that will need more people with a wide and balanced educational background than with an intensive specialist background. On the other hand, the present intensity of scientific activities throughout the world is such that the tendency to undue specialisation will increase rather than diminish, unless steps are consciously taken to guide educational trends.

Many of the problems facing the educational system are in no way characteristic only of Wales but are found in all modern industrial countries. The following extract from the American publication *Scientific Progress, the Universities and the Federal Government*, issued by the President's Science Advisory Committee in November 1960, is relevant: 'Simply in terms of economic self-interest our proper course is to increase our investment in science just as fast as we can to a limit not yet in sight.' However, a great responsibility here rests on all who are concerned with education. The rapid development of the new kinds of 'science-based' industries makes it extremely difficult to prepare the recruit of today for the industry of tomorrow. The only way this can be properly done is to increase the content of basic science (on which the technological developments depend) in higher education, rather than to attempt to provide a particular specialisation here and now. In this way, the recruit will be better equipped to adapt himself to later technological development. It is thus necessary to look at the educational system in Wales today to find whether it is well adapted to meet the new and different demands.

With this object, it may be helpful first to examine the modern Welsh scene with particular reference to the remarkable industrial changes which are affecting the social pattern, particularly of South Wales, and their implication in education. This will now be done in the following chapter, after which we shall discuss in Chapter III what we regard as the essentials of a balanced education.

Chapter II

THE GROWTH OF INDUSTRIAL WALES

2.1 Historical Survey

Wales is one of the most highly industrialised countries in the world, despite the high proportion of its area which is mountainous and sparsely populated. Ministry of Labour returns show that just over 55 per cent of the insured workers are employed in basic and manufacturing industries, of whom only 2·4 per cent are engaged in agriculture, forestry and fishing. The remaining 45 per cent are employed in the service industries, of whom about 11 per cent work in the distributive trades, 25 per cent provide professional and administrative services and nearly 9 per cent are occupied by various aspects of the construction industries. By far the greatest concentration of industry is found in the narrow coastal belt of South Wales and its adjoining valleys, although in recent years there has been much industrial development in north-east Wales. The South Wales coalfield is one of the most compact highly-developed industrial areas in Europe.

However, industry in Wales is not a recent development. Copper, lead and gold were worked in a small way in Wales as early as Roman times and coal was mined by the monks of Neath Abbey in the thirteenth century. Industrialisation in a wider sense can be said to have started when Elizabeth I granted a charter to the Mines Royal Society in 1564 to establish a copper works at Neath. Ore from Cornwall and later from Anglesey was worked in the Swansea area. The nineteenth century saw a great increase in the rate of industrialisation, based largely on the great variety of excellent coals found in a comparatively small area in South Wales, but rapidly extending to the manufacture of iron and steel and some non-ferrous metals. Towards the end of the nineteenth century South Wales held a pre-eminent position in the tinplate industry of the world. Wales also made its contribution to the development of important processes and techniques in these industries. Percy Gilchrist and Gilchrist Thomas* further developed and adapted the Basic Bessemer Process in two Welsh steelworks, which later transformed the iron and steel industry of western Europe. At Clydach, in the extraction of nickel a process is used which is based directly on chemical research. The process of copper extraction currently used throughout the world is based upon the 'Welsh' process. Agriculture is still an important industry, and it might be noted that the contribution of Wales to plant breeding has been recognised throughout the world.

After a period of prosperity, particularly in the heavy industries of coal, iron and steel, up to the end of the First World War, the first half of the present century was marked by the severe industrial depression of the inter-war years. The rate of unemployment in industrial South Wales was among the highest in Britain; but fortunately the post-war years have seen a great revival of industry, which is characterised by its greater diversity. Traditional industries are still important, however. Mining still employs one in ten of Welsh workers. Great developments in the iron and steel industry have taken place; all Britain's tinplate is now made in South Wales and the quantity exported amounted to 29 per cent of the world's trade in tinplate in 1962. Over one-quarter of Britain's total output of pig iron and crude steel is also produced in Wales. The oil industry, established initially in Wales at Llandarcy, has expanded rapidly; Milford Haven promises to become one of the big oil importing ports of Britain. Newport and Barry have seen large new sections of the chemical industry established. Nylon made in Monmouthshire and rayon in Flintshire provide examples of the relatively new industrial techniques of spinning synthetic fibres. Modern electrical industry in Monmouthshire and a wide range of light manufacturing industries at Trading Estates such as Treforest, Hirwaun and Bridgend all contribute to some diversity of Welsh industry. Power production in Wales shows a varied pattern not so far equalled elsewhere in the U.K. Developments of methane drainage schemes from coal seams, the utilisation of surplus gas from steelworks and the reforming of oil refinery gas contribute to the extensive gas grid built in the last decade; new coal-fired power stations will soon be augmented by two atomic energy power stations now under construction in North Wales. The pumped storage scheme at Blaenau Ffestiniog is the first of its kind in the United Kingdom.

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* Gilchrist Thomas was a Clerk of the County Court in London who, after visiting his family in South Wales, became interested in steelworks. He acquired considerable knowledge of chemistry through attending evening classes (see H. A. L. Fisher–*History of Modern Europe*).

The flourishing state of Welsh industry is indicated by the figures in Table 2.1.

Table 2.1 *Industrial Production**

Industry	Rate of Increase in Production in 1954–60	
	Wales	United Kingdom
Metal Manufacture	41%	22%
Gas, Electricity, Water	50%	33%
Construction	25%	18%
Other Manufacturing	32%	22%
Milk	23%	15%

Many of the newer industries are dependent for their continued prosperity on active and vigorous research in various fields of applied science and this aspect of recent developments will be discussed more fully in Chapter XIII. There are very few large research laboratories in Wales; most firms depend on research carried out in central establishments in England. This has educational implications for the University and technical colleges in Wales doing advanced work. In such institutions high academic standards, as far as science and technology are concerned, are only maintained if those engaged in advanced work have time and opportunities for carrying out research and for keeping abreast of developments in their chosen fields of work. Thus contact

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*Professor Brinley Thomas—*Western Mail Industrial Review.* 1962.

between industrial and academic research would be to the advantage of both. For the reasons mentioned above, this close contact is less easy in Wales than in England.

2.2 Industry and the Educational System

If we consider first the University of Wales, we see that from their foundation the constituent Colleges have developed scientific studies along with the humanities. The University Colleges at Cardiff and Swansea, particularly, stressed the scientific side as their links with local industries were strong. For example, when the University College of South Wales and Monmouthshire was established in 1883, Departments of Mathematics, Physics, Chemistry and Biology were among the first twelve—the others being Greek, Latin, Logic and Philosophy, English and History, Welsh, French, German and Music. In the College's first year 50 out of the total 151 students were taking chemistry. Article XXVI of the Charter of the University of Wales gave the Council power to recommend the establishment of a University Board of Technology for the purpose of promoting technological education and research, and of conducting enquiries into methods of improving industrial and commercial processes. Subsequent developments within the University have led to the establishment of departments of applied science concerned with such technologies as mechanical, electrical and chemical engineering, mining and metallurgy as well as others.

The Welsh Intermediate Education Act of 1889 led to the establishment by 1902 of 95 schools, the aim of which was to provide a ladder for the most able elementary school pupils to enter the University. The provision of physics and chemistry laboratories in these schools made possible the teaching of the physical sciences; and an adequate flow of students into the science departments of the Colleges of the newly founded University of Wales was thus ensured.

Thus, the Welsh educational system has always accorded a significant place to the teaching of mathematics and science right from the later years of the nineteenth century. Furthermore, an education both in the sciences and in the humanities was made available to all members of the community and not restricted to any particular class or section. On the other hand, in the industrial communities, developments in technical education which took place in Wales before the First World War were not comparable with those in industrial England. The attitude of the Welsh people towards education as preparation for posts in industry and commerce was adversely affected by the industrial depression and high unemployment of the inter-war years. Many parents saw the secondary school, the training college and the university as a means of providing their children with a way out of the insecurity of those years by entry into the black-coated professions. The result was that Wales trained more teachers, both primary and secondary, than could be employed there. Few pupils saw an opportunity for themselves through a career in industry, which tended to become identified with semi-skilled work in the industries of those parts of England which had avoided industrial depression.

In spite of the changed situation in industry in Wales today, the attitude of some parents and some heads of schools towards industry is still coloured by events of a generation ago. Parents and pupils need guidance on the range of opportunity offered by modern industry for able pupils who leave school at 16 or 18, especially if they are well-qualified in mathematics and science. The Council's report, *Technical Education in Wales*, 1961, dealt with the considerable expansion of technical education which has taken place in the Principality since the Second World War. Much of that report has a direct bearing on this remit. It is sufficient at this stage to note that about one-tenth of all young people between 16 and 21 are released by their employers for part-time day education in a technical college. We would note, however, a disturbing aspect of the position relating to student apprentices and craftsmen. Information given by the Minister of Labour in the House of Commons in May 1962 showed that Wales has by far the lowest proportion in Britain of boys and girls entering industry as craft apprentices or learners. The figure of 19 per cent compares very unfavourably with the British average of 35 per cent and the best area figure of 45 per cent. There are too few places for the numbers of school leavers. This is particularly true of the sparsely populated counties of mid and north-west Wales which provide little or no opportunity for industrial apprenticeship. Socially, there is the additional point that Welsh-speaking boys have to seek such opportunities in areas where they can no longer use their mother tongue, and their loss to rural Wales is considerable.

In addition to automation in the heavy industries, the mechanisation of agriculture, mining, quarrying and routine packing and manufacturing processes, which formerly employed large numbers of unskilled men and women, inevitably leads to a situation in which there are fewer opportunities for the school leaver with insufficient technical background. The absorption of the lower ability group into modern industry will be one of the big social problems of the future. The increased complexity of much modern plant and the speed with which processes become out of date and have to be changed will make greater demands on industrial workers, as we have indicated previously. The Government White Paper of 1961 stressed that such workers will 'require increasingly high degrees of skill in specific fields, coupled with the capability of being trained as new techniques cause changes in the nature of the work.' The Industrial Training Council points out that transfer from one job to another will become more and more common, and work people 'will require a mental flexibility which can only be developed by further education after the end of full-time schooling.' We shall return to this subject later.

The secondary school has to produce young people not only capable of skilled work in modern industry but also willing and able to lead a full life in a highly organised community, to retain a balanced outlook in the face of social pressures, to be responsible in behaviour and to be capable of profiting from the increasing amount of leisure provided by an age in which the machine has removed much of the drudgery from life. In short, they must be good citizens as well as good workers.

In the evidence we have received both from industrialists and from industrial organisations there was complete agreement with the view that it is the prime function of a school to produce boys and girls with a good *general* education. The evidence also showed that education would not be balanced without an adequate content of mathematics and science as well as of the more traditional elements of humane and aesthetic studies. However, it was clear that industry did not appear to be entirely satisfied with the standard of mathematics and science teaching in the schools. The wish was expressed, too, that teachers should be generally more clearly aware of what happens in industry so that they can illustrate their lessons by referring to applications of fundamental principles.

As an example of this concern, we were glad to note that the South Wales Area Training Committee of the British Iron and Steel Federation has, during the last three years, organised annual residential conferences in South Wales for science teachers. It was, however, disappointing to find that out of the 88 teachers who attended, 23 only came from 19 Welsh schools, while the remainder came from the rest of the United Kingdom. It would appear that the concern expressed by industry on this matter is far from baseless.

Evidence from industrial sources reflects a concern at what are considered to be weaknesses in some aspects of the work of the schools. For instance, it is stated that pupils often leave school with a serious lack of knowledge of fundamental scientific principles, even after passing the Ordinary Level examination of the General Certificate of Education. They may have all too frequently committed to memory a series of disconnected facts unsupported by experimental work and rapidly forgotten when the examination is over. Too few pupils are, it was suggested, receiving a foretaste of genuine science and an opportunity to apply this knowledge thoughtfully and with understanding. The teaching of mathematics is similarly criticised. It has been pointed out that most secondary modern school pupils, and indeed many of the less able grammar school pupils, who seek craft apprenticeships in Wales have had a mathematical education heavily biased towards computational skills in arithmetic. Boys frequently lack fundamental knowledge of geometry on which to base their later studies of engineering drawing. Their inability to understand simple algebraic processes makes a quantitative approach to the study of science difficult for them. We received complaints that such deficiencies have to be remedied in the early stages of their careers by industry itself and colleges of further education.

Industry seems to be well aware of the difficult problem facing the secondary modern schools in teaching pupils of less than average ability. Industry has, however, to employ these young people and it is suggested that there is a wide range of jobs at operative, and indeed in some cases at craft, level for pupils whose educational attainment would correspond to that of 'B' or 'C' streams in a five-form entry secondary modern school. It has been stated that 'the aim should be to get a far larger proportion of the bulk of secondary school pupils to reach this level in at least the key subjects, and it is as desirable to devote financial and material resources and good teachers to this end as it is to use them on courses leading to the various external examinations for higher ability groups. It is essential that the great mass of school leavers from the secondary modern schools should, when they enter industry, be able to speak clearly and make themselves understood, to read and understand instructions which are frequently of a technical nature, and to write grammatically and spell accurately.'

2.3 Summary

This chapter considers briefly the broad relationships between education and industry.

The attitude reflecting the old reluctance to taking up a career in industry is now changing among parents and heads of schools, but parents and pupils need guidance on the range of opportunity offered in modern industry.

The change-over to 'science-based' industries, as well as more frequent transfer from one job to another, will demand a higher degree of adaptability from industrial workers.

School leavers will need greater opportunities for continuing their studies in colleges of further education by an extension of part-time day release to many more young workers in industry.

Chapter III

LIBERAL EDUCATION IN THE AGE OF SCIENCE AND TECHNOLOGY

3.1 Historical Retrospect

The concept expressed by the words 'liberal education' is one which has undergone a series of modifications from classical times. The Greeks and Romans regarded training in the 'liberal arts', of which originally only freemen could avail themselves, as a preparation for active and responsible participation in public affairs and government. The 'illiberal' arts (*artes illiberales* or *sordidae*), on the other hand, were merely to equip men for particular crafts or trades which were considered unworthy of a freeman. The former were for the privileged few, the latter for the unprivileged many.

With the growth of the Roman Empire the liberal arts became less and less the prerogative of freemen, and this development was later furthered by the growth and spread of Christianity. The Church, in theory, did not recognise the older distinction between 'freemen' and 'non-freemen', but there were other factors which prolonged the classical view that a liberal education was not for all classes of society. These were the conception of a graded society and the belief that each grade should enjoy the form of training suited to its needs without reference to individual ability and aptitude. The basic mediaeval conception of the purpose of a 'liberal education' was that it should equip for their responsibilities ecclesiastical and lay rulers; and it was the Church which supplied a formal definition of the 'liberal arts', in two groups of three and four subjects respectively, all studied through the medium of Latin. The *trivium*—grammar, dialectic or logic, and rhetoric—meant, in modern times, reading, writing and the logical ordering of thoughts, and the *quadrivium*—arithmetic, geometry, music and astronomy—meant numeracy in relation to practical computation, geography and natural history, sound and harmony and the movements of the heavenly bodies. There was no dichotomy between the arts, in the modern sense, and such knowledge, observation and experiment as we would call scientific. Together the seven liberal arts were a foundation in both literacy and numeracy, but the limitations of scholastic inquiry, with its conception of a static universe and of a revealed and final truth embodied in the teachings of the Church, militated against experiment and led to a petrification of human thought unfavourable to exploration of the physical world. On the other hand, scholasticism lay behind the establishment of universities where specialist studies in theology, law and medicine were pursued only after a broad preliminary training in the liberal arts. Thus the mediaeval university, the primary aim of which was to train theologians, lawyers and physicians, produced men who, before specialisation, had been educated in arts which were more fundamental and wider in application than their specialist studies.

The Renaissance represented a revolution against mediaevalism which had a profound effect on the theory and practice of education. Latin gradually yielded to the vernacular languages, new national entities appeared, the emphasis on the individual increased, and greater confidence in the power of reason encouraged observation, exploration and experiment. This last development ushered in the natural sciences, but the established forms of education were slow to allow them a place in their programmes. However, economic changes culminating in the Industrial Revolution, which called for trained workers, led to a demand that persons outside the traditionally privileged classes should have the benefit of an education which should be of a different kind from that offered in the past. By and large it was meant to be practical and vocational but even at the lower levels it contained many elements which were liberal in content and in effect. At the same time the growth of experimental science gradually changed men's ideas about the universe and it was increasingly felt that the new ideas, and the methods which led to them, should be accepted as an essential element in a well founded system of education.

Despite these developments, by the middle of the nineteenth century, but little provision had been made for the formal teaching of science. With the establishment of the Honours School of Natural Science at Oxford in 1850 and the Natural Science Tripos at Cambridge a year later, there came a change in the official attitude towards science teaching. Outside the establishment, as it were, this change had been anticipated, on a lower level, by the type of education provided in the Nonconformist Academies where a practical and almost rationalist approach to knowledge was allied with religious instruction. In Wales, the Nonconformist attitude was later reflected in the provision made in the Welsh Intermediate Education Act (1889) for the teaching of science in the schools and in the fact that certain science departments in the University of Wales are amongst the oldest in Great Britain. In Wales, too, because of a difference in class structure, the schools and the University provided for classes of people who were not, in general, catered for in England; and it is significant that some of the first science teachers produced by the University were persons who were steeped in Welsh culture, and who made their own contributions to it in music and poetry.

Thus, by a series of modifications of the classical concept of a liberal education, was reached a point where science won a place side by side with the arts in a general education up to the age when specialisation begins. In England and Wales, specialisation (in arts or science) formally begins in the sixth form of the grammar school, but options in the lower forms can prematurely determine the nature of that specialisation. To-day there is a danger that science, not content with a place side by side with the arts, will become their rival. Already there are those who argue that an education in science can produce the broad humane qualities which, more conservative educationists maintain, training in the arts alone can produce.

3.2 The Contemporary Need for Balance in Education

Modern economic, political, scientific and technological developments combine to demand a new assessment of 'liberal education' in terms relevant to the present and to the immediate future. The recognition of science as a valid element in education, the achievements of scientists and technologists, and the economic need for producing more and more scientists, technologists and technicians have resulted in claims for a still more prominent place for science in a general education and for an increasing number of people to be specially trained in science. This development can be a threat to the belief that education is as much for the individual as it is for society as a whole. There is, too, the danger that our society will not enjoy a single common culture, but two divergent cultures: the scientific culture, dynamic and forward looking, enjoyed by the scientists and technologists, and the humanistic culture, tending to be out of touch with modern life and thought, enjoyed by those predominantly trained in the arts. Sir Charles Snow and others would maintain that this 'split culture' is already a fact, whereas others argue that the fact is of no great importance inasmuch as a thorough training in the arts or in science can have the same results in terms of human thoughts, habits and attitudes, which ought to be the prime concern of education in the broad and liberal sense.

Education, it must be agreed, implies knowledge; and so much of our most recently gained knowledge is of a scientific kind that no properly educated person ought to be left ignorant of the more important aspects of it and of its impact on the life of the individual and on the society to which he belongs. Such knowledge is important not merely for its own sake, but also for a balanced appreciation of the problems which confront mankind. This poses the question how much science and arts teaching must all persons receive to enable them to play responsible parts in a modern democratic society. Science and scientific knowledge are likely to increase in importance in the future, and an awareness of this has resulted in economic and political pressure for placing an even greater premium on scientific, technological and technical studies. The arts may well find themselves relegated to an inferior position, which would be wrong inasmuch as scientific discoveries and inventions are not the only forces which mould our lives. Religious, political and social ideas also play their part, and humanistic studies appear to be as relevant as science to an appreciation of these. Any dichotomy between the arts and the sciences is to be deprecated, and the present tendency towards such a dichotomy calls for a fresh synthesis of arts and science which will aim at giving all persons not only a training in particular specialisms, but also a basic general knowledge of major human activities and an awareness of man's power and responsibilities in a changing society. Such a synthesis, if it is to be valid, must be one which can be practically applied at each stage of the educational system and, in particular, at the general stage which must precede any stage of specialism.

A liberal education must transcend mere vocational training. Its aim is the fullest possible development of the individual's physical, intellectual, moral, and aesthetic powers both for his own sake and for the sake of society. It must supply a balanced awareness of man in the physical world, an appreciation of his past, his present and his potential future, and the ability to communicate with others in words, spoken and written. It must foster powers of judgment so that men and things can be properly evaluated. These aims must largely be an ideal, but any system of education will be liberal only to the degree that it succeeds in the practical realisation of this ideal. At certain stages training for a vocation cannot be ignored, but such training must never be given at the expense of denying the higher aim of education, which is to develop each person's natural faculties as fully as possible. Not only must there be non-vocational studies on a broad base; the actual vocational training must be pursued against as wide a background as possible so that it contributes to a person's general development. Thus alone will the needs of the individual and those of society be met equally.

Vocationalism or specialisation of training *on its own* is a negation of the aims of a liberal education. Ideally, vocational training should be deferred for as long as possible; for the most important contribution of education must be in terms of what men have in common as individuals and as members of society. Against this, one must place the practical consideration that the demand for specialisation is increasing, that each specialism requires more and more of the individual, and that the necessity for him to apply it as a citizen places a limit of time beyond which it cannot be postponed. Hence there must be an effort, at certain stages, to strike the most effective balance between instruction of a vocational kind and the broader non-vocational studies, to decide the timing and grading of non-specialist and specialist work, and to ensure the fullest possible integration between them.

Science cannot be considered in purely specialist terms. It affects the daily life of each individual practically, intellectually, morally and aesthetically. It has given man not only new knowledge, but also the means of acquiring more knowledge and the possibility of applying it to satisfy human needs. Education cannot ignore this development: science is such a force in man's life and environment that a degree of acquaintance with its methods, the results of its discoveries and their actual and potential applications is necessary for all. The older view that scientific studies are the negation of humanism cannot be defended. To-day education, if it is to be liberal in the sense that it equips a person for a responsible role in the affairs of men, must ensure that all have in common a basic knowledge of science and its results as well as a basic knowledge of the major human activities outside the domain of science. In the interests of an integrated society there must be one broad common culture in which scientists and non-scientists can be mutually intelligible, can understand the general principles and implications of their respective specialisms and can seek a correlation between them.

The current educational problem is fundamentally the age-old dilemma of trying to reconcile permanency and change. What makes it more difficult to-day than in the past is the rapidity of the contemporary revolution, the force of its impact on all the human race, and the heightened demands that will be made on moral as well as intellectual judgment if the new and expanding knowledge is to be for the advancement of mankind. And this problem has to be faced in an age when a liberal education cannot be the prerogative of the few but must be the inalienable right of each individual. 'Education for all' must be made to mean not a more liberal education for some and a less liberal one for others, but an education approximating more and more to the liberal ideal, for more and more people. Therefore all studies most conducive to such an education must be allowed each its proper place at every stage, and the study of any specialism must be pursued in the way best calculated to give that specialism its fullest meaning in relation to other specialisms and to the sum of human experience and aspirations. This task, not easy in itself, is made more difficult by certain contemporary factors, of which some are general and some apply to Wales in particular.

3.3 Basic Factors

3.3.1 *Some General Considerations*

It is now national policy to ensure that the greatest increase in the number of those progressing beyond the secondary stage of education shall be amongst those who undertake scientific, technological and technical studies. As a result, individuals may be led to suppress what natural ability they may have in a non-scientific direction and attempt to develop what may be but moderate ability in science. This is a form of conditioned diversion of aptitude where the needs of society may appear to conflict with those of the individual. In the long run, both the individual and his society may suffer thereby. If, at some future time, a scarcity value were placed on the humanistic specialist, the result might well be a forced diversion of aptitude in the contrary direction. The natural corollary is that a liberal education must aim at educating all persons as long as possible in terms of their highest common factor in ability, aptitude and need and defer as long as possible the necessity of choosing between divergent specialisms which require different aptitudes for the most successful pursuance of them. The older a person is, the less likely are external pressures to divert him from developing his natural aptitude. With the present demand for increased teaching of science it is imperative that there should be a balance and all possible correlation between science and humanism so that the best in both may be moulded into a common culture.

There is, also, the problem of inter-communication, which must always be of prime importance in any system of education. Both scientists and non-scientists must be trained to wield language with accuracy and precision so as to be able to express the newer as well as the older concepts. However much they may vary in knowledge of scientific and non-scientific activities, they must be able to communicate with each other in the spoken and written word, on as wide a basis as possible of common knowledge and understanding. In the first place this means mastery of the mother tongue and, where the mother tongue has only a restricted currency, proficiency in the language of widest currency within his own country; but contemporary trends towards a European community suggest that for an increasing number proficiency in an additional language or languages will become desirable.

Moreover, science has its special language, mathematics, which like science itself knows no national boundaries. There is no need to stress that scientists must be numerate; but non-scientists, too, need a basic knowledge of mathematics. Scientists and non-scientists alike need to be both literate and numerate; and the higher the common level they attain in both literacy and numeracy, the greater will be the degree of intelligible inter-communication between them and the greater the coherency of their society and culture. Such is the probable future into which we are moving that all persons should be trained in language and mathematics for as long as possible.

3.3.2 *Factors Special to Wales*

There are certain additional factors in Wales which need consideration. Western culture, on the humanistic side, can be broken down into a number of national cultures, but science is basically universal and there cannot be national or regional variations of its fundamental search for truth. Now any attempt to form a synthesis, in educational terms, of science and the older culture implies a blending of the newer universal element with the humanistic element which shows variation from nation to nation. In Wales, it is such a variation which is the *raison d'être* for its separate Central Advisory Council for Education, which is itself a recognition that Wales has special problems of her own bearing on any approach to a liberal education.

The first special factor is that of language. In recent years the Ministry of Education, the University of Wales and public bodies have shown a more sympathetic recognition of the Welsh language than at any time in the past. As yet the official policy of bilingualism has not been successfully implemented on as wide a scale as could be wished, but this policy may well become further complicated by pressure for a more general teaching of a continental language. Even now a grammar school pupil who wishes to study French has often to sacrifice the study of Welsh even when it is his first language. This is a violation of the sound principle that every person ought to be trained in the use of his mother tongue and taught other subjects through the medium of it. Furthermore, a pupil studying Welsh, English, Latin and French carries a heavier linguistic load than his opposite number in England and this is a relevant factor in the problem of the balance between arts and science studies at all stages up to the Ordinary level of the General Certificate of Education. We say more about the place of the Welsh language in Section 3.5.

The second special factor in Wales is what was until recently the general attitude towards science. The main emphasis in education in Wales has been on the humanistic tradition embodied in the arts, and there was a certain distrust of technical education. Nor is it without significance that these studies found an earlier and easier foot-hold in the anglicised and industrial areas than they did in more predominantly Welsh areas. Thus there developed a general feeling that there was an alien element associated with the newer studies, and that they were more vocational than educational. Something of this feeling still persists in many ways such as the preference for the grammar school over the technical school, the preference for the university over the college of advanced technology, and the tendency for many of those trained in the newer studies to regard the Welsh language, its literature and its general background of rural life as an anachronistic survival which cannot have any real significance or future in the new world of science and its accessory studies. This general attitude is due, in part, to the predominantly urban location of technical institutions in the industrialised and anglicised areas, where the links with the Welsh-speaking areas are tenuous. At the same time it owes something to what was the prevailing concept of the function of technical institutions—the concept that their purpose was to provide technical and vocational training only, and that they were not concerned with education in the broader sense. Despite a general improvement in the growing recognition of the desirability of combining technical education with more general humanistic studies, it is still true to say that technical schools and colleges find in Welsh life a less congenial soil than does the grammar school or the university. The attempt at an alliance between the traditional humanistic aspect of education and the newer scientific and technical developments is very recent, and even that attempt shows but little regard for what may be called the Welsh variant of the older European humanism.

The two factors already discussed combine to form a third factor in which the linguistic and 'scientific' factors are in mutual reaction. On the linguistic side, one has to admit that the Welsh language, which developed naturally into a vehicle of expression for the older content of western culture, has not yet done so for scientific, technological and technical thought. The fault does not lie in the language as such. Bearing in mind that scientific and technical terms are very much alike in most European languages, the natural resources of the language appear to be adequate, but the demand for Welsh as a vehicle for the newer studies is severely restricted.* On the other hand, this lack of demand, especially at the higher levels of education, impoverishes the language and stunts its growth. This is all a vicious circle, and at root, a reflection of the challenge inherent in the newer culture, which is by nature universal and supra-national, to minority national entities and their respective languages (and all that is associated with them). The Welsh language cannot survive as a medium to express the whole gamut of human thought and activities unless it succeeds in embracing the newer culture of science, technology, and technical studies. This the language can only do if it is used and so allowed to develop its natural resources. This is being done in primary schools and training colleges and, to a lesser degree, in secondary modern and grammar schools where it is necessary, but it appears that very little is being done in technical institutions. It is suggested that technical and technological education, in any attempt to be more liberal, should pay due heed to the non-technical aspects of European culture not only in the broader context but also in their particular relation to Wales. A broad culture has real meaning only in its concrete manifestations within any given national unit. This is an argument for giving not only the Welsh language but also the literature, history and traditions of Wales a proper place in any programme for the inclusion of humanistic general studies as part of a technical education. Such programmes as exist at present seem to pay but scant, if any, attention to such studies in their Welsh context. The adoption of a policy along the lines suggested above might halt the trend of Welsh society to split into two halves, the one half industrial, anglicised and economically surging forward with confidence, and the other half largely rural and agricultural, predominantly Welsh in language, still distrustful of the newer developments, and tending to live nostalgically on its heritage from the past instead of seeking a new heritage in the present and the future.

3.4 General Principles

In the light of the foregoing discussion, the ideal at which a modern liberal education must aim is very well expressed in President Eisenhower's Science Advisory Committee statement:†

> 'A modern educational system should not only sharpen the intellectual capacities and curiosities of each new generation, should not only extract the essential core from ever-accumulating stores of knowledge, should not only find ways to produce new leaders equipped to add to these stores and to create all the new tools that the civilisation requires; it must also produce citizens and leaders who will know how to use the knowledge and tools to advance social and cultural life . . .
>
> The end is clear: to introduce the growing child, the youth, and the adult to the best and essential elements of the intellectual and cultural experience of previous generations; to do this in such a way that we stimulate curiosity and encourage each individual to look forward, not backward, to develop

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* That the natural resources of the Welsh language can cope with modern science is shown by *Y Gwyddonydd*, a scientific quarterly journal recently launched by the University of Wales Press Board.

† *Education for the Age of Science*. United States Information Service. London, 1959, pp. 5–6.

his own talents to their maximum, and to continue this development through his life.'

As the above quotation implies, in modern society, where education is for all, there must be, at certain stages, some vocational element; but if an education is vocational and nothing else, it ceases to be liberal. It must help to develop each person's inherent ability and aptitude to their utmost, both in the specialist field for which he may be trained and in as many other fields as possible. The older idea that a liberal education meant 'anything or everything except science' is no longer valid; nor can an exclusive training in science, without reference to the humanities and to moral and aesthetic values, be considered a liberal education.

During his training a person must learn to know himself intellectually and emotionally, to know his fellow men and the ways of the world—things which generations of men learned without either literacy or numeracy, a consideration which suggests that a liberal education implies the development and use of human powers independent of anything which a formal education may give in addition.

Both the individual aim of 'education for leisure' and the social aim of 'education for effective democratic citizenship' must be attained. The ideal means for accomplishing this purpose would be, in its broad connotation, a new synthesis of the humanities, in the older sense, and science and technology which are themselves humane in that they represent human activities impelled by man's inherent powers of intellect and emotion.

The synthesis of culture in educational terms will be decided in the long run, not by individual theorists, but by the climate and force of public opinion. Already that opinion has forced upon educationists and others the problem of trying to work out a new synthesis. The various reports and statements that have appeared show that it is not difficult to define as an ideal what is being sought in a liberal education to suit modern and future needs, but they also show that the translation of the ideal into the practical is not so easy a task.

Because of the present pressure from science and technology, educationists tend to show a greater general concern for the broad humane education of the scientist, the technologist and the technician than for the education of the non-scientist in scientific matters; but a workable combination of the older and newer studies is equally desirable for those whose main activities and interests will be in the humanistic sphere. In order to feel at home in the new world, the latter, too, need a basic understanding of the methods, the discoveries and the applications of science. Therefore there must be provision, at each and every stage of education, for a combination of studies designed in purpose, content and method to represent all major human thoughts and activities, so that all members of society may have a common basic awareness and knowledge relevant to the present age. Nor is this the only purpose of such studies: they must serve also to foster an attitude of curiosity towards the things of the mind and spirit and of responsibility for the dignity of human beings and their power to build for the future. To-day we are witnessing the paradox of having, on the one hand, better facilities for the education of all and, on the other, such low standards of popular taste as are reflected in certain types of entertainment and other aspects of contemporary life. One of the fruits of widespread educational facilities should be to enhance one's realisation of the value of education as a lifelong process, and to lead to an improvement of popular taste.

The above considerations lead us to suggest the following general principles for a liberal education relevant to the present day:

physical, moral and aesthetic qualities should never be neglected in an endeavour to develop intellectual qualities;

education should be along broad lines, including arts, mathematics and science, for as long a period as is reasonably consistent with an individual's ability and aptitude; early specialisation or premature options, which predetermine the nature of specialisation at a later stage, should be avoided;

every effort should be made to remove any impression of a dichotomy between the arts and the sciences and to stress the correlation between them; every person should be allowed to develop fully any special aptitude he may have, whether in arts or science;

a special place should be given to the mother tongue, not only as a subject of study but also as a medium of instruction;

vocational training, when it becomes necessary, should always be supplemented by wider non-vocational studies;

formal education should impart a realisation that true education is a lifelong process.

3.5 The Place of the Welsh Language

Historically, Welsh is the national language of Wales, with a literature, especially in poetry, which has continued in unbroken tradition from the sixth century to the present day. This national language is no longer the mother tongue of the majority of the people of Wales; it is spoken by a minority only, about 26 per cent, but any system of education which aims at being democratic and liberal must recognise a language which is still spoken by 656,000 people in a total population of about 2,600,000. Since the language is the main key to Welsh culture as a variant of western culture, it is something which ought to be of intimate concern even to the non Welsh-speaking element in the population of Wales. Since monoglot Welsh-speaking Welshmen are now few in number and the great majority of Welsh speakers are able to use English with varying degrees of facility, the linguistic problem in Welsh education is to determine the place which ought to be given to both Welsh and English in the various grades of the educational system. The Ministry of Education has declared itself in favour of a policy of bilingualism.

This leads us to the following conclusion:—A person has the right to be taught in his mother tongue and to be taught other subjects through the medium of that language; and the right to acquire as great a mastery as possible of a second language. This second language would be either English or Welsh. English is the nearest language of wide currency which is also the language already spoken, as a first language, by 74 per cent of the population of Wales and, as a second language by about 25 per cent. Welsh is historically the national language of Wales and the key to Welsh culture, as much as English is the key to English culture.

At present there is too often a break in the main medium of instruction when a pupil moves from the primary to the secondary school, whether it be a grammar or modern school. A pupil whose first language is Welsh ought to be allowed to continue the process of mastering his mother tongue in the same way as a pupil in England is expected to continue his study of English. It is well known that a language cannot be fully mastered when it is taught merely as a subject; mastery of it comes only with increasing facility in the use of it in dealing with as wide a range of subjects as possible. At present, with English as almost the exclusive medium of instruction, and Welsh taught merely as a subject on a par with any other modern language, the pupil's proficiency in English, in which he is taught other subjects, outstrips his proficiency in Welsh; and what was originally not a first language develops into the normal medium for the discussion of other subjects.

A questionnaire which the Council sent out to all secondary schools in Wales revealed that an attempt is being made to use Welsh as a medium of instruction in science and mathematics in only four per cent of secondary modern schools and in 6.5 per cent of grammar schools and schools with grammar streams. It is estimated that about 13 per cent of the teachers of science and mathematics in the latter schools are at present able to teach their subject through the medium of Welsh.

We would recommend that, in Welsh-speaking areas, greater use should be made of Welsh as a medium of instruction in both mathematics and science. We are encouraged to do so in view of the facilities now being offered at two of the training colleges and in university departments of education in Wales. The University Faculty of Education's technical terms panel has compiled and circulated an experimental list of terms in physics and will shortly circulate a similar list of biology terms. *Termau Mathemateg* (Mathematical Terms) has already been published by the University of Wales Press and *Termau Mathemateg Uwch* (Higher Mathematical Terms) put in hand, whilst *Termau Technegol* (Technical Terms) contains a section devoted to chemistry. For some years it has been possible for students at the Bangor Normal College and Trinity College, Carmarthen to choose to be taught in Welsh, and the University School of Education makes provision for their examination to be conducted in Welsh. This development would have a greater practical impact if teachers who are bilingual and trained to teach mathematics and science through the medium of Welsh could be assured of employment in Wales.

3.6 Welsh Background Studies

All pupils in Wales, whether they have an aptitude for language or not, should in the course of their education—if it is to be liberal—be made aware of the culture of the community of which they are members. For a full understanding of this culture a knowledge of Welsh is necessary, for every national language develops into something far more than a medium of communication on the ordinary plane. This does not mean, however, that no awareness of the culture of Wales is possible without a knowledge of Welsh.

We agree with the Council's statement, in its report on *The Future of Secondary Education in Wales* (1949), that the 'language problem' in Wales is but part of a wider one. This wider problem is that of making pupils, through education, aware of the distinctive features of Welsh society and the relationship of that society to the larger world. Although the continuing vitality of Welsh in speech and in writing is the chief testimony to Welsh culture, that culture is more extensive than the Welsh language. It manifests itself in music, arts and crafts, in social history and in the visual arts.

How can the Welsh pupil, more especially in this context the Welsh pupil whose first language is English and who may for various reasons be unable to learn Welsh, be given some understanding and appreciation of this social and cultural environment? In the primary school there ought to be no great difficulty if the 'subjects' normally taught there are linked with the child's immediate surroundings. For secondary school pupils there is much to be said for a unified course on 'Contemporary Wales', including history, geography and literature, as was recommended in the report on *The Future of Secondary Education in Wales* (1949). Although it was recommended that such a course should be taken by all pupils, Welsh-speaking and non Welsh-speaking alike, and that its medium should be English or Welsh according to the linguistic character of the school, it is clear that non Welsh-speaking pupils are in greater need of it.

Bearing in mind the core subjects we regard as desirable for a broad liberal education and which we discuss in Chapter V it would be difficult to make such a course compulsory at the pre-Ordinary level in the grammar school. Some of the core subjects, however, ought to be used to attain the same purpose. The foundation for a study of history, for example, should be the history of Wales, which would necessarily more than touch on the history of Britain and that of other lands. So, too, the study of geography should begin with Wales and then proceed to the British Isles and the wider world. And the teaching of history should include something about the development and vicissitudes of the Welsh language, the growth of its literature, and the social and religious life of its people. Later, in the sixth form, aspects of 'Contemporary Wales' could well form part of the course on 'general studies' which this Council regards as desirable.

In the secondary modern schools a course on 'Contemporary Wales' could very well be given, although here, at least as much as in the grammar school, the study of history and geography, whether as separate subjects or in combination, should begin with the history and geography of Wales.

In technical colleges a similar course could form an integral part of the general studies, concerned with humane and wide scientific problems, which are being advocated as a 'liberal' counter balance to the purely technical and technological instruction.

It is laid down in the Regulations of the University of Wales School of Education that the training colleges 'will provide instruction in the general background of Welsh life through lectures and other appropriate activities'. This is as it should be, but to-day the background of Welsh life is to a considerable extent scientific and technological. Hence, the 'instruction in the general background of Welsh life' ought not to be planned in exclusively humanistic terms, but should also embrace its newer aspects—the very aspects which are often at war with the traditional aspects, as was suggested earlier.

In this chapter we have emphasised that education must aim at providing a programme of studies designed in purpose, content and method to strike a balance between scientific studies, on the one hand, and humanistic studies, on the other, so that each member of society, no matter what his specialism may be, has a common basic knowledge of the two branches of study, is able to seek a correlation between them and can appreciate, in varying degrees, their relevance to his immediate as well as to his wider environment. No educational system can be completely changed at once. There must be a succession of changes in the wake of changes in public opinion and changes in the needs and aspirations of society. On the pages which follow we note certain changes which appear to us desirable, at various stages within the present educational system, so that a closer approximation to a liberal education may be attained. Whether they are practicable or not, only experience can show.

3.7 Summary

There is a contemporary need for a synthesis of arts and science which will enable the individual to play a responsible part in a modern democratic society. Education should be along broad lines, including arts, mathematics and science, for as long a period as is reasonably consistent with an individual's ability and aptitude. Early specialisation should be avoided.

Vocational training, when it becomes necessary, should always be supplemented by wider non-vocational studies.

If the trend of Welsh society to split into two parts, the one industrial and anglicised and the other rural and Welsh, is to be halted, the Welsh language must play its full part in scientific studies. We recommend that, in Welsh-speaking areas, greater use should be made of Welsh as a medium of instruction in both mathematics and science.

PART II

THE CONTEMPORARY EDUCATIONAL SYSTEM

Chapter IV

THE PRIMARY SCHOOLS

4.1 The Child at School

The relationship of teacher and pupil is fundamental at all stages of education, but the dependence of the pupil on his teacher is greatest in the primary school. The attitude and educational background of teachers in primary schools, as well as facilities and conditions for teaching, are therefore of paramount importance. The curriculum at the primary stage should not be considered in terms of subject divisions. This is a period of 'romance and wonder', in which all the constituent elements of the curriculum should be closely interwoven.

Since the war there has been a gradual change in the pattern of primary school work, though the change has been more marked in some schools than in others. General class instruction, with its emphasis on imparting facts and techniques, has been giving way to an approach which demands more active participation by the child; from being passively taught, he is increasingly being encouraged to co-operate by learning through first-hand experience, discovery and understanding. It is at the primary school age that a child develops his attitude to learning and that the teacher has an unrivalled opportunity for opening up new avenues of interest, understanding and appreciation of a wide range of activities. The best primary schools today are far more exciting places to be in than they were even a generation ago, but in too many schools such new and desirable developments are impeded by the existence of classes which are too large to allow a close personal relationship between teacher and child.

Primary education is valuable in its own right; it is not subordinate to the secondary stage of education, though it leads on naturally to it. We believe that the chief aim of the work in the primary school should be the development of the child's ability to express himself in language—through speaking, reading and writing. Mathematics and science also have an important part to play at this stage, but it is only through enlightened teaching that they can contribute to the full development of the pupil. In this way children have their curiosity and imagination stimulated, their knowledge increased, and their respect for accuracy and truth strengthened. The development of such attitudes and qualities is not the exclusive prerogative of the teaching of either mathematics or science, but these have their own important contribution to make towards laying the foundations of a liberal education in the primary school.

4.2 Mathematics

The last twenty years have seen some interesting developments in infant schools. In many, mathematics has come to mean far more than formal written sums on the four rules of arithmetic; it has been enriched by the inclusion of a great deal of practical work in counting and measuring of different kinds. The stress at this level is now placed on giving the young child a broad practical experience as a necessary base on which to build a coherent structure of mathematical thought.

It is recognised that many junior schools realise the need for a new approach to the teaching of mathematics; nevertheless, in many others, the subject still remains formal and over computational in character. Computation is an essential part of mathematics at this stage, but it is a means to an end and should be introduced and graded as individual pupils are ready for it. The child's attitude to mathematics is vitally important and the way in which the subject is presented and developed is crucial. Children can be taught to carry out mathematical processes quite skilfully, but still have little understanding of what lies behind these processes. In many schools children acquire arithmetical skills by rule of thumb and they are often unable to follow the reasoning involved in a simple problem. There is evidence that some of the traditional work in such complexities as long multiplication and division of compound quantities is gradually disappearing in the schools and this trend is to be encouraged.

There is need for continuity of method between the infant and junior schools and again between the junior and secondary schools. If the child finds that some of the techniques learnt in the junior school are of little relevance when trying to cope with mathematical ideas at the secondary school level, he may develop a negative attitude to the subject and soon lose interest. This work in the primary school should be thought of as mathematics and not as arithmetic only. With the development of computing machines the need for clerical arithmetic is much less than it was. The range of work covered will depend on the ability of the child, but all, at this level, need a broader mathematical education. Before leaving the junior school, pupils should know the addition and multiplication tables, and their knowledge should be based on practical experience of numbers, including the decimal system.

There are other important aspects of mathematics at this stage. There is a place for much more experience of measurement and spatial relationships. Spatial study, where attempted, has generally been confined to mensuration; space has other important and interesting properties. Children can distinguish shapes long before they become interested in measuring size or length, and, with his intuitive awareness of symmetry, the child can be encouraged to experiment with shapes. Spatial study, in all its aspects, is a rich field for mathematical experiment, discussion and enjoyment.

Concrete experience should generally precede the formulation of principles. Enough has already been done in recent years to show that attitudes and understanding can be very much improved through well chosen practical work and experiment. Many schools use various types of apparatus such as those recommended by Dienes, Stern and Cuisenaire. These appear to be popular with both pupil and teacher, and can be a valuable aid in bringing order and pattern to early mathematical experiences. To what extent such equipment is ultimately effective is still a matter for teachers to investigate. We believe that more experiment and research is needed on various types of practical work for different ages and levels of ability in order to discover what is most rewarding and most economical in time and energy for the creation of interest and the development of understanding and confidence. The teaching of mathematics has to be a wise blend of exposition, discussion, practical work, experiment and discovery, together with drill in facts, relationships and techniques necessary for raising the pupil's level of thinking and for increasing his mathematical power. Far too many teachers at present lack the mathematical background to make this possible.

4.3 Science

In general, children of today have a greater awareness of the applications of science than their parents had at the same age. Their interest stems from a great variety of sources, and it is right that the schools should encourage and give direction to this interest. A child's curiosity and sense of wonder in natural phenomena are present from the earliest years, and to neglect these in his early education is to ignore a most important phase in his development. In the primary school, children are eager explorers and investigators, and they respond readily to the experimental method of 'Let's find out'. As they grow older, this attitude is all too often lost and replaced by an unquestioning acceptance of the teacher's authority or of the printed word.

The essential nature of science—the universality of its basic concepts—belongs to a much later stage in education. Generalisation is a process that is usually beyond the capabilities of a child in his formative years at the primary school. In the primary school all that can be expected is that children should enjoy their science as a personal experience, observing and discovering for themselves, and not being compelled to memorise a series of facts presented to them by the teacher.

The advice given two hundred years ago by Jean-Jacques Rousseau on the introduction of Emile to science is very much the approach to learning we would advocate in the primary school of today. 'Teach your scholar to observe the phenomena of nature; you will soon rouse his curiosity, but if you would have it grow, do not be in too great a hurry to satisfy this curiosity. Put the problems before him and let him solve them himself. Let him know nothing because you have told him, but because he has learnt it for himself. Let him not be taught science, let him discover it. If ever you substitute authority for reason he will cease to reason; he will become a mere plaything of other people's thoughts.'

From evidence we received it is clear that, although there is a growing awareness of the need for a new approach, in many primary schools science is presented as a series of stated facts, and for this reason serves but little to develop independent thought and a questioning attitude of mind. To achieve improvement in primary school science we need to concern ourselves more with *how* we teach science than with *what* we teach, more with method than with content. This is not to deny the importance of content, nor the delight which primary school children obtain in the collecting of facts, but the attitude of mind that is formed in searching for facts and the paths to knowledge which are opened up during the search are more important at this stage than the facts themselves. We should be at pains to train children to think and help them to see and solve simple problems for themselves by devising their own experiments and apparatus.

On this view, therefore, we believe that science should be brought in as an integral part of the child's environmental studies, which would include the experience and understanding of simple phenomena, Much must depend, however, on the scientific background of the teacher, who should be able to understand the scientific basis of these phenomena.

It is thus clear that science in the primary school is not a subject that demands elaborate specialist equipment, although facilities for simple experiments should be available; indeed, the teaching of science would suffer were it to become tied to a laboratory. Nor is it possible to be precise about the amount of time to be allotted to it, for this will vary from school to school and will depend upon the extent to which the work in science overflows into other aspects of the curriculum. What is certain however is this: that science well taught can make an important contribution to the general work of the primary school by training children to think and to question, by quickening their interest in the world around them, by affording valuable links with the teaching of history and geography in a scheme of local studies, and opportunities to use and consolidate skills acquired in other fields such as speech, reading, writing, mathematics, model-making and handicraft.

4.4 Selection for Secondary Education

Our survey of selection procedures used by the 17 local education authorities in Wales revealed differences of emphasis within a fairly consistent pattern of testing. All but three authorities made use of external examinations in English (and Welsh, in some instances) and in arithmetic; the latter is most commonly examined in the form of standardised tests and in the examination of language use is made either of unstandardised or standardised objective tests.

It is not within our terms of reference to comment upon the effectiveness of these procedures as a means of allocating pupils to the appropriate form of secondary education. We are concerned, however, with the effects that these particular selection tests have on the content and treatment of the curriculum in the junior school. From evidence we have received, it is clear that the pressures exerted by excessive preparation for these examinations are affecting the breadth and balance of work and potentialities of development in most junior schools. The preoccupation of the individual teacher with the requirements of these various attainment tests is understandable; he is faced with a competitive examination and he has to live in his community—a community which sets great store upon the value of a grammar school education. Understanding, as opposed to mechanical skills, is important both in the field of language and in that of mathematics. On the linguistic side, preoccupation with these so-called objective tests hinders the child's development in expressing himself in speech and writing, and we would stress the importance of practice in continuous writing. Equally, in mathematics the requirements of these tests highlight speed of performance in the mechanical skills of computational arithmetic, an aspect which we have criticised above. Preoccupation with such skills by a teacher does not encourage the provision of a richer and more varied mathematical fare.

A feature of the modern primary school is the increasing time taken by such valuable activities as simple dramatic work, music and dancing, art and craft. However, this has generally meant less school time available for mathematics. Examinations have still to be taken at the same level as before, when more time was available, and this has tended to encourage the teaching of the kind of mathematics which is most easily acquired through routine drilling. This means that while we see much in junior school work which stimulates and delights the children, in the teaching of mathematics the practical work and experiences needed to reinforce the pupils' knowledge often go by default. Furthermore, although it is realised that children differ greatly in individual ability and mathematical maturity, too little attention is given to this fact, particularly in schools which are preoccupied with the requirements of the standardised tests. Very often the ablest and the weakest pupils follow the same courses.

We are led to the conclusion that the pressures exerted by the kind of examination in current use at the 11-plus stage have in many cases a detrimental effect on the full development of life and work in the junior schools. A child at this stage in his education needs every opportunity for satisfying his natural curiosity, interests and creative instincts. He needs to acquire confidence and skill in the use of his mother tongue, through speech, reading and writing. At the same time he must be encouraged to find his place in his community.

4.5 Summary

The broad base of a liberal education must be laid in the primary school.

Classes are still too large and there is a great need to reduce their size.

Much of the work in arithmetic is still over-computational in character. Children at this stage need a broader mathematical experience.

Science, as a specific subject involving an organised body of knowledge of natural phenomena, has no place in the primary school. We believe that it should be brought in as an integral part of the child's environmental studies. The emphasis should be on observation and discovery, based upon the child's natural curiosity and sense of wonder.

The pressures exerted by the kind of attainment tests in current use at the 11-plus stage have a detrimental effect on the breadth and balance of work, and the all-round development of the pupils, in the majority of junior schools.

Chapter V

THE SECONDARY SCHOOLS (UP TO 16 YEARS OF AGE)

5.1 Distribution of Pupils

The numbers of pupils (of all ages) in maintained secondary schools in Wales in January, 1962 and 1963 were as follows:*

Table 5.1 *Distribution of Pupils*

	1962	1963
Secondary modern schools	87,951	84,988
Secondary grammar (including grammar-technical) schools	58,648	58,886
Secondary technical schools	1,517	1,537
Secondary bilateral and multilateral schools	7,384	6,753
Secondary comprehensive schools	22,337	23,082
Other secondary schools	558	331
Total	178,395	175,577
Number of grammar (including grammar-technical) schools in Wales	111	110
Number of pupils in these schools	58,648	58,886
Number of other secondary schools in Wales with pupils doing work up to 'A' level	45	48
Number of pupils in these schools	29,721	29,835
Estimated number of 'grammar' pupils in these schools (based on 33 per cent)	9,900	9,950

From these figures it will be seen that 49 per cent of the total are in secondary modern schools and 33 per cent are in grammar (or grammar–technical) schools. For the sake of comparison it is noted that in England 61 per cent of all pupils in maintained secondary schools are in secondary modern schools and 24 per cent in grammar schools. The estimated number of 'grammar' pupils in other secondary schools in Wales doing work up to Advanced level is about 5 per cent of the grand total, so it will be seen that approximately 38 per cent of all pupils in maintained secondary schools in Wales follow a 'grammar-type' education.

This percentage, however, is based upon the total number of pupils in the whole secondary age-range of 11 to 18 or 19 years and, as the majority of pupils leave school at the age of 15 or 16, this percentage is consequently boosted by the fact that there are pupils in the older age groups in schools doing work up to Advanced level. It is more appropriate to determine the percentage of 13 year old pupils in schools of different types, and the figures for January, 1963 in England and Wales, are given in the following table:†

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* *Statistics of Education*, 1962 and 1963. Part One. H.M.S.O.

† Ministry of Education, List 69 (1963).

Table 5.2 Thirteen-Year Old Pupils

Type of School	Modern per cent	Comprehensive per cent	Grammar per cent
England	64·2	5·5	18·4
Wales	57·4	12·3	26·1

It will be seen, therefore, that the proportion of pupils of secondary age following a 'grammar-type' education is on either basis still higher in Wales than in England, and this is a factor which has to be borne in mind when considering the organisation and curriculum of the grammar and modern schools in Wales.

It should be noted, also, that the secondary technical school in Wales has never been developed even to the extent that it has in England. The Council, in its report, *The Future of Secondary Education in Wales* (1949), recommended a pattern based on (a) the multilateral school or (b) a dual system consisting of grammar-technical and modern-technical schools. The argument was that the separate technical school was likely to interpret technical education in too narrow and vocational a sense up to the age of 15 or 16. In 1947 there were 24 secondary technical schools in Wales, with a total of 3,350 on roll, but since that date most have been closed and the pupils absorbed into grammar-technical and modern-technical schools. At present there are six separate technical schools in Wales.

5.2 A Basic Curriculum for all Pupils up to 16 Years of Age

The present-day curriculum of the secondary school, of whatever type and in particular of the grammar school, is to a considerable extent the result of tradition and the fluctuating demands of society. Its growth has been largely external in origin, a process of addition, of proliferation of subjects rather than a considered re-arrangement of its structure in accord with some governing educational principles such as those which we have discussed in Chapter III. Every consideration of individual subjects, viewed in isolation, tends, in the nature of the case, to result in the putting forward for each a claim, in itself impressive, to a larger place in the curriculum. The claims of individual subjects need therefore to be seen in a wider perspective; there would seem to be necessary some regulative principle, which will yield a scale of priorities against which the place of individual subjects should be considered.

Whatever specialised aims a secondary school may pursue, its aims must *at least* include that of providing a general education. We are, therefore, suggesting an outline of what, in our view, are the basic requirements of a general education. This should be underlined; the wider implications of such an education are subtle, ramified and complex; what we are attempting here is a brief statement of that irreducible minimum of experiences or subjects which should form part of the curriculum of every boy and girl, in any kind of secondary school, from 11 to 15 or 16. Obviously, other subjects will be added to it in the final curriculum but only in the time left over when these prior claims have been met. No doubt other views of such a minimum are possible but what is insisted upon here is the need for some such minimum range of experiences which can provide the framework within which the place of other subjects should be considered. It should be noted also that we are not concerned here with levels of achievement in any of these subjects. These will vary with the ability of the pupils.

In our opinion such a basic curriculum for all secondary schools should include the following:

Language and Literature—It would seem hardly necessary to justify their inclusion to the end of school life but there is often the temptation to undervalue them, particularly in the face of growing scientific, technological and vocational claims. Whatever else may be added to it, the study of language, as a means of expression, is central to the education of all pupils as the main instrument of consciousness, of understanding and communication. With it must be coupled literature, not knowledge about literature but literature as an exercise in personal response, as a deepening and extension of the pupils' sensibility.

In Wales the linguistic position is such that due place must be given to both Welsh and English, as noted above in 3.5. Pupils whose first language is Welsh (which ought to be their main medium of instruction in the primary schools) must continue beyond the primary school level the process not only of learning Welsh, along with its literature, as a subject in itself but also of using it as a medium of learning for other subjects. At the same time such pupils cannot be denied a training in English and a knowledge of its literature. In other words, Welsh-speaking pupils must be expected to study both Welsh and English and their respective literatures. For some Welsh-speaking pupils the study of a third language will be valuable, and they ought never to be placed in a position where they have to choose between Welsh and any such third language, for example, French.

The majority of pupils will have English as their first language, and their principal training in language and literature must be through English. Such pupils, however, have a cultural right to acquire a knowledge of Welsh, historically the national language, and its literature. They must be given the opportunity of studying Welsh as a second language; and if they wish to take an additional modern language, it is highly desirable that the necessary facilities should be provided. If they have the necessary aptitude they must not face a choice between Welsh and some other language. It is a reasonable educational aim in Wales to make the teaching of Welsh as a second language available to as many pupils as possible, whether they study a third language or not.

History and Geography—A liberal education should make a pupil aware of his place in society and the place of that society in space and time. Geography, in its physical and human aspects, will help him to appreciate the nature of the society to which he belongs and the relationship of that society to the wider world. History will give him something of the time element, as also will geology. Intelligent living in the present and an enlightened attitude to the future are possible only with some knowledge of the past; nor can a sense of social identity and co-operation—of 'belonging' to a particular community which is itself a part of a wider community—have any substance without some realisation of how we have become what we are. History can train the mind, kindle the imagination, and help the child to understand the place of his society in the wider community of nations. Five years is not too long a period for such a study. Let it be added, however, that ruthless selection is a *sine qua* *non*, and that the correlation of history with geography, literature and other subjects is most important at all relevant points.

Science—Science is one of the great achievements of the human intellect, by which men gain an increasing understanding of the nature of the material universe. Its progress has been so marked since the beginning of this century and its discoveries and applications in technology have attained such far-reaching importance in the lives of us all that it must take its place as one of the basic studies at this stage of education. All should have some acquaintance with the experimental methods of science and a knowledge of some of its basic principles and greatest achievements. We are in full agreement with the views* of the Association for Science Education that 'Science should be recognised—and taught—as a major human activity which explores the realm of human experience, maps it methodically but also imaginatively, and, by disciplined speculation, creates a coherent system of knowledge'.

Mathematics—The case for mathematics rests not merely on the fact that it is the 'Handmaid to the Sciences' or that it is a necessary skill in the conduct of some everyday affairs. It also rests on the claim that mathematics, liberally interpreted, can bring precision and order into the scheme of things. As well as being a powerful tool, it is a way of thought, and one of man's effective ways of reducing complexity to something simple enough for him to comprehend and control.

The Arts and Crafts—In a society where success tends to be measured in external or material terms the Arts occupy a peripheral place. It is not surprising then that their place in the secondary schools—particularly the grammar schools—is also marginal and, in the competitive struggle that takes place in the curriculum after the first two or three years, art, crafts and music are the first casualties.† In considering the significance and richness of the role of the Arts in the education and formation of the young, we are concerned with activities which are central to the development of the whole person, with expressive media other than the merely verbal, with creative activities through which the individual can explore and project his own response to life, with forms which humanity has found necessary throughout the ages to express and illuminate its experience. If the educational system is to produce balanced persons and implant the qualities of taste and discernment, then it cannot limit itself to an exclusively verbal and academic curriculum; it must find room for creative expressive experience. We are of the firm opinion, therefore, that the experience of an art or craft should be ensured for all pupils in secondary schools in this basic curriculum.

Physical Education—It is hardly necessary to make any special plea for its inclusion. The exercise and care of the bodies of the young have from the earliest times been a prime element in education. In this age of material comforts, ease of transport and prolonged sedentary work, they are more important than they have ever been.

Religious Instruction—We recognise in this feature of the life of a school a significance which extends beyond that which belongs to a 'subject' in the curriculum. Christian values are written large in our social and educational institutions and in one form or another influence profoundly our outlook and conduct as individuals. We believe this to be a matter of paramount importance and we return to it in considering the school as a 'good society' in Chapter XVI.

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* *Science and Education.* A Policy Statement. 1961, p. 5.

† 'The time-table of the fourth and fifth years of the grammar school course is seriously congested, and yet in most schools the practical and aesthetic subjects have ceased to be really available for the abler pupil.' 15–18. A Report of the Central Advisory Council (England), 1959, p. 220.

In regard to the study of the Bible in our schools, we wish to record our opinion that the Revised Syllabus* recently published is a work that should be available and used in all the schools of Wales. It will, we feel confident, provide both valuable guidance and renewed inspiration for teachers at all stages.

The above then represents what seems to us to be the basic minimum curriculum, to which the demands of special interests would have to accommodate themselves. We are here concerned only with what seems to be essential for all pupils in *all* types of secondary school up to the age of 16. There are subjects which, although not considered basic for all, are nevertheless of value for many pupils. An example would be another language, studied as a medium of communication and for a deeper understanding of its literature and of the people who speak it. This outline, however, is concerned only with the need for determining some kind of minimum range of experiences as essential to the idea of a general education. The place given to a particular subject must then be such as to attain the desired end. Any consideration of subjects in isolation, outside the context of such an over-all view, runs the risk—if the claims are too large for a given subject or group of subjects—of failure or of prejudicing the aims of a sound, general education.

We now proceed to consider the place of mathematics and science within the framework of a balanced curriculum in the secondary school up to the age of 15 or 16.

5.3 Mathematics

5.3.1 *General Considerations*

Much of the evidence we have received indicates that the criticisms of the teaching of mathematics in the primary schools apply also to the secondary schools. It frequently happens that greater attention is given to the acquisition of skill in techniques, for example, in arithmetical computation, in algebraic manipulation and in geometrical drawing, than to the understanding of underlying principles and relationships. The importance of techniques cannot be denied, indeed understanding sometimes comes with practice in the development of a technique, but, as a general rule, mathematical education based on techniques alone will be sterile. Many of those who use mathematical methods do not understand *why* they work; they understand only how to use them. The art of mathematics teaching, therefore, is to promote understanding of the processes which is sufficient to the pupil's intellectual satisfaction and to his needs.

Understanding, in this sense, is not the prerogative of the very able pupil, although he would be expected to have a much deeper understanding than one of modest ability. Experience in recent years in some schools has proved that pupils of average and below average ability are capable of much more ambitious work than the mechanical computational arithmetic which has

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[*] *Revised Syllabus of Religious Instruction for the Schools of Wales* (University of Wales Press, 1963).

been their lot in so many schools. The needs of life in a modern society, too, demand a broader mathematical education for them. The lower one goes down the intelligence range, the more necessary it is to present mathematics in a tangible or visual form, and the less can one rely on verbal argument and description. It is also true that a great deal of one's creative thinking in mathematics is rooted in the experimental and conjectural; it is basically inductive in approach despite the fact that, in its final form, mathematics is expressed deductively. The able pupil can experiment in the abstract with symbols and ideas but the less able pupil needs to have his earlier creative phases more closely related to things that can be seen and to practical jobs that have to be done. The complaint is frequently made that many pupils cannot retain mathematical knowledge. This may be due to the work being pitched at too abstract a level. Another reason might be that the work is presented in an ineffective context in the first instance and, as a result, no real mathematical awareness is formed in the pupil's mind. One of the main problems of the teacher is, therefore, to present mathematics in a context which has significance for the pupil and is at a pitch commensurate with his level of understanding.

As in other subjects, the most important factor in the presentation of mathematics is the teacher. Even the good teacher, however, has to consider different modes of teaching and vary his method of attack to meet particular situations. In the past the dominant mode of teaching has consisted of exposition at the blackboard together with class discussion and written exercises. 'Chalk and Talk' will continue to play an important part in class work, but we would emphasise that there is need for greater individual attention than is often the case at present. We believe it to be of first importance that the pupil should be given the opportunity of taking a positive part in the learning process. He should learn through doing as well as through listening. Thus, although the formal lesson will continue to be an effective instrument of learning, there is need to give pupils more time for individual experience through various activities such as measuring, drawing, recording observations in various ways, constructing models and diagrams, simple surveying and other exercises in finding out for themselves. In this way curiosity is stimulated, discoveries made and intuition formed.

5.3.2 *In the Secondary Modern School*

The danger of making a mathematical course an assortment of bits and pieces should be guarded against. There should be continuity and coherence, reflecting growth in ideas and maturity, and some thread of logical development running through the course. The importance of continuity at both ends, too, should be borne in mind; at one end, continuity with the work of the junior school and, at the other, with vocational interests and after-school requirements. We believe that some of the work might be reorientated and developed in the last year or two in order to give it a vocational flavour. To avoid misunderstanding, we stress here that we advocate such vocational flavouring not for the purpose of training for a specific employment but as a means of strengthening the pupils' general education. This part of the mathematics course should be considered in conjunction with syllabuses for craft courses and general courses at colleges of further education, not in order that these syllabuses should dictate the work to be done in the schools (which we would deprecate deeply) but rather to ensure continuity and growth in the individual's mathematical education and to avoid much of the unnecessary and tedious repetition of work that is now seen, all too frequently.

In some secondary modern schools, which assign too prominent a place to arithmetic at the cost of neglecting the wider context of mathematics, all the work in technical drawing is left to the woodwork or metalwork master. This is unfortunate, because, if the craftsman is to be responsible for technical or engineering drawing, as no doubt he should be, the preliminary work should be associated with mathematics. Drawing is essential for a study of shapes and this is a traditional part of mathematics. It is a natural and pleasurable activity and, as a subject, can be easily graded to suit the needs of the able and the less able. It is regrettable that the tendency to regard technical drawing as a separate subject, often divorced both from mathematics and from a craft, seems to be on the increase. We would urge that it should be taught in its proper context, integrated with the mathematics syllabus in the early years, and at a later stage with the craft syllabus. As in all other branches of mathematics the important thing is to give the pupil a sound foundation. In drawing he is more likely to receive this in the earlier stages from the mathematics teacher than from the teacher of technical drawing with his insistence from the very start on highly accurate drawing and on the use of conventions which in the early stages might be difficult to assimilate.

5.3.3 *In the Grammar School*

We believe that up to the age of 15 or 16, the over-riding aim should be a broad mathematical education for all and not one which will be rewarding only if pursued to a higher level.

An appreciable number of pupils will complete their mathematical education at the end of the fifth form year and every effort should be made to make it as comprehensive and complete in itself as possible. These pupils should acquire some ability in mathematical thinking, some expertise in techniques and procedures and, above all, an appreciation of the place and value of mathematics in life.

The time allotted to mathematics in the grammar schools of Wales is usually adequate and sometimes generous. The teaching time ranges between one-eighth and a little over one-sixth of the total weekly time. The following table, based upon replies to a questionnaire sent by us to all grammar schools and schools with grammar streams in Wales, shows that no schools give fewer than four periods in a 35 period week and nearly 40 per cent of schools give, on average throughout the school careers of pupils, the equivalent of more than a lesson a day to the subject.

Table 5.3 *Time Allocation for Mathematics*

Average Time Allocation in Periods per 35 Period Week	Number of Schools		
	Boys	Girls	Mixed
Fewer than Four	—	—	—
Four to Five	15	19	47
Five to Six	11	8	28
More than Six	1	—	3

To give much more than one-sixth of the time to mathematics would, in our opinion, militate against other subjects and activities necessary for a sound, general education. Any improvement in mathematical education must, therefore, be sought not in extension of time but in improved quality of method, content and organisation. As we have said, the fundamental basis and aim of mathematics teaching is understanding; without this the subject is barren. It is all too easy to convert the subject into techniques which smother understanding. Thus the teacher has to keep a balance between manipulative skill and understanding. Although the essence of mathematics is deductive reasoning it has long been realised that the earlier stages at least of learning depend on experience, in short, on inductive methods. The teacher is well aware of the dangers of too authoritarian an introduction to his subject and he arranges for a preliminary stage during which the pupil can look around and become familiar with new media, learn a new vocabulary, discover and acquire new concepts and new modes of thinking.

There are other important factors in teaching. Mathematics entails discipline and drill. Nevertheless, it should always involve a degree of satisfaction; children like doing things as long as they are successful.

We have received a strong body of evidence criticising the mathematics taught in the schools today. The division of mathematics into arithmetic, algebra, geometry and trigonometry, it was urged, should be broken down, during at least the first two years of the course. We were informed that sometimes the same form may have a different teacher for each branch of the subject; the amount of formal geometry taught is still great and that too much time is spent on purely manipulative arithmetic and algebra.

There is little doubt, in the light of modern developments in mathematics, that there is a strong case for some modification in school work, both in content and in treatment, especially for the abler pupils. Syllabuses are much in need of revision. Much of the mechanical computation in the teaching of arithmetic should go; for example, long multiplication and division of compound quantities, heavy fraction manipulation and a fair amount of commercial arithmetic. These are time-wasting procedures which involve few important principles. In algebra, too, far too much time is devoted to manipulative work, to complicated algebraic expressions and to trinomials, and too little to new ideas and the logic of the subject. Ideas in modern mathematics can be presented in an elementary way and the ideas and notation of a set, subset, union, intersection, etc., with much of the concomitant symbolism, provide a common language that should be used wherever appropriate from the early stages. We urge that every effort should be made to ensure a synthesis of the branches and that, for instance, trigonometry should not be studied in isolation, as it tends to be at present.

Even if there is no case for a radical change, there are undoubtedly minor adjustments that could be made. Surely young people in this age should have some acquaintance with scales of notation other than the denary; an appreciation of the binary scale and its application in the electronic computer is well within their grasp. A little modular arithmetic, too, would be a refreshing change. Some understanding of simple ideas of probability and statistics would not be amiss. On the more practical side, too, pupils might be made aware of the existence of instruments such as the slide rule, planimeter and pantograph.

An assessment of the effectiveness of the new ideas can be made only by actually trying them out on the pupil. This does not mean committing a whole national system of education to an experiment—but it does mean encouraging the conduct of experiments in individual schools where there are highly competent mathematics teachers who believe in the changes. Already there are groups of schools working along these lines and, no doubt, the progress made and schemes of work evolved both in this country and abroad will be studied with great interest.

Pupils differ widely in mathematical ability and maturity; it is wrong to expect everyone to pursue exactly the same course at exactly the same pace. An increasing number of teachers are realising that five years is too long for the good pupil to spend on the present Ordinary level course: on the other hand, an appreciable minority find difficulty with it. We consider that there is a strong case in Wales, with its relatively high grammar school intake, for a course which would trifurcate after two or three years to provide for (a) pupils who have a flair for mathematics, the future mathematicians and scientists, who could cover both the Ordinary level and the Additional Mathematics courses in the five years in the main school, (b) the majority of pupils for whom the Ordinary level course is suitable, and (c) the less able who now give up mathematics for arithmetic only—their work should not be confined to arithmetic.

Additional Mathematics can be taken with, or independently of, Mathematics O or O(T). It is intended for able candidates in the fifth form who can be expected to cover more ground than the average candidate in the main school course. The number of pupils now taking Additional Mathematics is only about five per cent of the number taking mathematics at the Ordinary level.

When the General Certificate of Education was introduced in 1951, the Secondary School Examinations Council laid down that arithmetic could no longer be accepted as a subject of examination. In order to meet the needs and wishes of the schools, the Welsh Joint Education Committee decided to provide an examination in arithmetic outside the G.C.E. and of a standard roughly comparable with the arithmetic questions in the Mathematics Oa paper. Entry to the examination is limited to those who are either candidates for the G.C.E. or already hold a G.C.E. The number of candidates has increased considerably since the examination was introduced in 1952.

The arrangement whereby pupils are allowed (or advised) to drop the full mathematics course after the first few years and prepare for the Special Examination in Arithmetic can have a deleterious effect on the work, especially in the third year: some pupils, realising that they can soon give up algebra and geometry, ease off in their efforts and not only retard their own progress but act as a drag on their class. As will be seen from the following table, based on the results of our questionnaire to all grammar schools and schools with grammar streams in Wales, the number of schools which permit some of their pupils to drop mathematics at various stages up to the age of about 16, is disturbing.

The practice of dropping mathematics involves substantial numbers of pupils in individual schools. Returns, from the schools providing this information, showed that an average total of about 2,400 pupils a year, of whom nearly 2,000 are girls, are allowed to drop the subject at some stage in their main school course. Only about a fifth of these schools expect all their pupils to take mathematics up to the Ordinary level stage and make no provision for special classes in arithmetic.

Table 5.4 Duration of Mathematics Study

Mathematics dropped after:	Number of Schools			
	Boys	Girls	Mixed	Total
First Year	—	1	1	2
Second Year	1	7	13	21
Third Year	2	14	37	53
Fourth Year	1	3	20	24
Not dropped at all	23	1	7	31

We regard it as serious that such a large number of pupils are allowed to drop the full mathematics course and take the Special Examination in Arithmetic. It is our considered opinion that the study of mathematics is an essential part of a balanced education up to the Ordinary level stage and that preparation for this examination is an inadequate substitute for the study of mathematics. We recommend, therefore, that the Special Examination in Arithmetic should be discontinued and that the substantial number of pupils who now confine themselves to arithmetic only should follow a course in mathematics devised at a level which is commensurate with their ability in the subject.

5.4 Science

5.4.1 *General Considerations*

For many years it was the practice that most boys were taught only physical science and most girls took only botany or biology. In recent years more boys have studied biology, whilst chemistry and, to some extent, physics have become part of the curriculum of most girls' schools; but we have received evidence that the traditional pattern is still far too common, especially in secondary modern schools. Running the modern home is itself 'applied science', both physical and biological, and many women handle more electrical apparatus in the home than men do at work. Knowledge of the human body, heredity, evolution and topics in microbiology all appear to be appropriate equally for boys and girls.

Science courses at this stage should contribute to an understanding of natural phenomena, and to an appreciation of some of the problems confronting the modern world. The lessons should meet the need of those pupils for whom a study of certain branches of science has a special appeal; they should provide suitable material for the precise and economical use of language; they should ensure that mathematical experience is gained in an interesting context, and they should develop skill of hand and eye in the design, construction and manipulation of apparatus. The science lesson above all provides ready opportunities for logical reasoning.

The emphasis at present, both in lessons and in examinations, seems to be on the memorisation of facts; the experimental approach, with investigation by the pupils themselves, is often neglected. Pupils need some appreciation of scientific method and the experience of recording accurately what they see.

Not all pupils have an aptitude for science, but most possess a natural curiosity and can be given some idea of the scientific approach to a problem. Geology, for example, is a particularly suitable subject for stimulating the curiosity of the pupil in the secondary modern school. Moreover, the subject lends itself readily to individual investigation by the pupil, who can be encouraged to make and display his own collection of geological specimens.

We believe that science is an essential ingredient in the general education of all secondary school pupils and it should form part of their studies throughout their stay in school. In our deliberations on the place of science in the secondary school we have sought a pattern which would not only provide a balanced education in science but also allow for other aspects of secondary school work which we consider indispensable for a liberal education. It will be convenient, as the Science Masters' Association has done, to consider the secondary course in three stages. Phase 1, up to 13 or 14 years of age, will be a broadly based course, followed by Phase 11 which covers the years 14 to 16, and Phase 111, which is dealt with in the chapter on the sixth form, embraces all sixth form science studies, including not only Advanced level work but also 'general' courses followed by candidates for entry into training colleges and full-time further education courses in an increasing variety of fields.

For Phase 1, we recommend a course which should be broadly based and include topics selected, on the basis of the pupils' interest and ability to understand, from physics and biology with a little chemistry, and perhaps some astronomy and geology. Correlation between the topics should be exploited wherever possible and, for this reason, Phase 1 is ideally taught by one teacher although, because of the scarcity of suitably qualified teachers, it will generally be found necessary to share the teaching between, it is hoped, not more than two teachers—a biologist and a physicist or chemist. Facts as such should not be over-emphasised and the work should be planned so as to stimulate interest in the subject and to whet the pupil's appetite for the future; to give them facility in carrying out simple laboratory experiments and in recording their own observations; to lead them to a better understanding of their surroundings; to provide them with opportunities for increasing their facility in the use of language, and for thinking logically about scientific problems.

5.4.2 *In the Secondary Modern School*

If school science is to be developed logically in association with experimental work, it is clear that the factual content of courses will have to be drastically reduced. It will need, too, a more generous time allocation in many schools, particularly the secondary modern. We sent a questionnaire to the 223 secondary modern schools in Wales, and received 200 replies. An analysis of the replies showed that the average teaching time allocated to mathematics and science, expressed as a percentage proportion of the total number of periods a week, ranged from a maximum of 28.8 per cent to a minimum of 12 per cent. The number of weekly science periods ranged from a maximum of seven to a minimum of two. We consider that it should be a matter for concern that 33 per cent of secondary modern schools in Wales give less than three periods a week to science. We have reason to believe that this is due, at least in part, to inadequacies of staffing, an aspect which we consider in detail in Chapter VII.

It is clear also from the evidence that many classes are too large for effective practical work. In secondary modern schools practical work is usually done by classes of over 30 and frequently of up to 40 pupils. We consider, therefore, that experimental work carried out by pupils in all aspects of science would be greatly facilitated by a limitation of practical science classes to a maximum of about 20 as soon as staffing permits.*

Phase II in the modern school should be a period of differentiation, when special aptitudes and interests, including vocational, lead pupils into appropriate extended courses. Some attention has been given to such courses for boys, and many of these have a technical bias; they are, however, often restricted in range and outlook, and designed to lead only into engineering apprenticeships. Extended courses are less common for girls and there is need to develop those which contain an adequate amount of science, including physical science, for those wishing to enter careers in nursing, catering and horticulture, and as demonstrators and laboratory assistants. A few rural schools have been particularly successful in adapting science courses to their environment. The modern school has the difficult task of coping with a very wide ability range. It is for this reason that attempts to provide courses that reflect differences in both the interests and the sex of pupils often fail, particularly in small schools. Consequently, it is better to provide a broadly based course in mixed classes for pupils of like ability. There may be, however, some advantages to be gained in the larger schools, particularly for the less able pupils, in teaching science separately to boys and girls in the later stage of the course; the work of the boys being linked with the workshop and garden, and that of the girls with the housecraft rooms.

5.4.3 *In the Grammar School*

There is no standard pattern in the organisation of science teaching in the grammar schools in Wales. Some schools teach the separate sciences from the beginning, others teach General Science for two or three years or even up to the end of the fifth year. It is usually in the fourth year that some pupils are allowed to study three science subjects with mathematics and this situation gives rise to strong criticism of lack of balance and of specialisation at too early an age. We point out, however, that some arts pupils, for example those studying three foreign languages, often find themselves in a similar position at this stage.

In the grammar school, Phase II covers the period when the pupil is allowed to select from a range of optional subjects and prepare for the Ordinary level examination of the General Certificate of Education.

It has been our contention throughout that the degree of specialisation in the third, fourth and fifth years should not be such as to deflect the aim of providing a sound, balanced education. It is clear, therefore, that at this stage few pupils can afford to give more than 10 periods a week (out of 35) to science subjects without incurring a deleterious effect on their general education; an effect which may, in some cases, even prejudice literacy. To attempt three science subjects to Ordinary level in this time is likely to reduce them to 'cram' subjects and diminish their educational value. It follows that, for all but a very small minority of gifted pupils, not more than two science subjects should be taken at this stage in preparation for the Ordinary level examination. In the case of the small number of pupils who will go on to take three science subjects (excluding mathematics) in the sixth form, it is perhaps better for them to bypass the Ordinary level examination in biology, and to begin their work for the Advanced level examination in this subject with a double period devoted to practical work in the fifth form. The science course should be developed from experimental work which is partly demonstrated by the teacher and partly carried out by the pupils themselves. The time given to practical work by the pupils themselves would normally be one double period a week in each subject and each class should preferably consist of not more than about 20 pupils.

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* This is the maximum normally permitted for practical science classes in Scotland. See the Schools (Scotland) Code, 1956, Reg. 15(2) (c) and (4).

Another context in which this whole question can be viewed is that of ensuring the best use of the science teachers that the schools have actually at their disposal. For a given number of teachers the choice in school organisation is inevitably between more science subjects per pupil and less time per subject and fewer science subjects per pupil and more time per subject. There can be no doubt but that the latter is much more likely to give the individual pupil a foretaste of genuine science, and to ensure a good flow of suitable pupils into the science sixth form.

Neither General Science nor Additional General Science in their present form is considered to be a good preparation for Advanced level work in science in the sixth form, though in some circumstances they may be satisfactory for some pupils. The former involves a very shallow treatment of too diverse a selection of topics, the latter an attempt virtually to cover three branches of science in about 10 periods a week.

A number of pupils at this stage will wish to take only one science. While it is thought that General Science may serve the needs of some of them, the importance of free choice and vocational requirements must always be considered. Biology will attract many pupils, especially girls, while science with an agricultural bias may best suit pupils in some well-equipped rural schools. The able future sixth form arts pupil might not be sufficiently extended by the limited intellectual demands of the General Science course but satisfied by the more exacting demands of physics. If circumstances are such that only one science subject is studied by a particular pupil, it has been suggested to us that chemistry is probably the least suitable subject for pupils taking only one science subject. The less able pupils who opt for one science subject could profitably devote more time to it (six or seven periods a week) and so achieve a standard which they would be unable to arrive at if their efforts were spread over a larger number of subjects. A course in physics, for example, would perhaps be of greater value to many of the pupils who now take Engineering Science.

Following on the latter point, we are uneasy about the proliferation of science subjects which can now be taken at the Ordinary level. The science subjects which are examined by the W.J.E.C. at this level are as follows: (i) Physics, (ii) Chemistry, (iii) Botany, (iv) Biology, (v) Human Biology, (vi) Geology, (vii) General Science, (viii) Additional General Science, (ix) Engineering Science, (x) Horticultural Science, (xi) Agricultural Science. We believe that it is to the advantage of pupils to concentrate at this stage on the fundamental sciences of physics, chemistry and biology, although General Science would be suitable for some pupils. The different interests of pupils could be met by variation of syllabus content to illustrate general principles within the framework of the fundamental science subjects. This point is considered in greater detail in Chapter VI.

We repeat that we are strongly of the opinion that the taking of too many subjects within either the languages or the science groups would detract from the aim of a balanced education at this stage. For example, three languages (other than the mother tongue) or three science subjects would, for the majority of pupils, involve a proportion of teaching periods which would allow too little time for other and equally important subjects in a general education.

5.5 Summary

The proportion of pupils following a grammar-type education is higher in Wales than in England. This factor should be taken into account when considering the academic calibre of pupils in the different kinds of secondary schools in Wales.

The claims of individual subjects should be considered only within the framework of a minimum range of experiences essential to a general education. Such a basic curriculum (up to the age of about 16 years) should include Language and Literature, History and Geography, Science, Mathematics, the Arts, Physical Education and Religious Instruction.

For pupils whose first language is Welsh, 'language and literature' will include both Welsh and English; and for pupils whose first language is English every opportunity ought to be given to acquire a knowledge of Welsh and its literature.

For some the study of a third language will be valuable and necessary. The pupil whose first language is Welsh must never be forced to a choice between Welsh and any third language; such a language ought to be in addition to Welsh and English. The pupil whose first language is English ought to be given every opportunity of studying Welsh as a second language, whether he studies a third language or not.

The over-riding aim in the teaching of mathematics at this stage should be a broad and balanced education in the subject for all up to the age of 15 or 16.

The teaching of mathematics in many secondary schools would be more effective if, in addition to the acquisition of skill in techniques, emphasis were laid on the understanding of underlying principles and relationships based on experience.

There should be greater continuity of method and content between the mathematics teaching in the junior and the secondary school. At the top of the unselective school, mathematics should be related to vocational interests.

We regret the tendency to regard technical drawing as a separate subject, often divorced from both mathematics and from a craft, and we recommend that the subject should be taught in its proper context, integrated with the mathematics syllabus in the early years and at a later stage with the craft syllabus.

Modification in the content and treatment of mathematics at this level is highly desirable. We would encourage, therefore, the conduct of experiments in individual schools.

There is a strong case in Wales, with its relatively high grammar-school intake, for a mathematics course which would trifurcate after two or three years to provide for (a) the abler pupil who could cover both the Ordinary level and the Additional Mathematics courses in five years, (b) the majority for whom the Ordinary level course is suitable, and (c) the less able who now give up mathematics for arithmetic only.

It is disappointing to find that only the small proportion of five per cent of all those taking mathematics at the Ordinary level are entered for the Additional Mathematics examination.

We recommend that the Special Examination in Arithmetic should be discontinued and that the substantial number of pupils who now confine themselves to arithmetic should follow a course in mathematics devised at a level which is commensurate with their ability in the subject.

The traditional pattern of choice involving biology for girls and physical science for boys is still too common, especially in secondary modern schools.

In order to encourage the experimental approach, now often neglected, the factual content of the syllabuses will have to be greatly reduced. Also, practical science classes should be limited to a maximum of about 20 pupils as soon as staffing permits.

There is need for a more generous time allocation in many schools, particularly secondary modern.

In order to achieve a balanced education in science we recommend that the course should be organised in the following stages. Phase I, up to 13 or 14 years of age, should be a broadly based course and should include topics, selected on the basis of the pupils' interest and ability to understand, from physics and biology with a little chemistry and perhaps some astronomy and geology. Phase II in the secondary modern school should be a period when special aptitudes and interests, including vocational, lead pupils into appropriate extended courses. In Phase II in the grammar school the majority of pupils should take not more than two science subjects in preparation for the Ordinary level examination.

Few pupils can afford to give more than 10 periods a week (out of 35) to science subjects without harming their general education. Fewer science subjects per pupil and more time for each subject (rather than more science subjects and less time per subject) should enhance the quality of education in science.

Neither General Science nor Additional General Science in their present form is considered to be a good preparation for Advanced level work in science in the sixth form.

We are uneasy about the proliferation of science examination subjects known as, for example, Engineering Science, Horticultural Science and Agricultural Science, which can now be taken at the Ordinary level. We believe it is to the advantage of pupils to concentrate at this stage on the fundamental sciences of physics, chemistry and biology. Alternative syllabuses within the framework of these basic subjects might well be considered.

Chapter VI

THE SIXTH FORM

6.1 A Balanced Curriculum

The distinguishing feature of sixth form work in the grammar schools of this country is the study in depth of two or three associated disciplines. We believe that this approach is sound, in that it is an appropriate final stage of the educational process which is traditional in the grammar schools of this country. It is right that the ablest pupils, at the age of about 17, should have the opportunity to develop their special interests and aptitudes, master some of the intricacies and come to some understanding of the real significance of their chosen fields of study.

Whilst endorsing the principles of specialisation in the sixth form we are, however, concerned about its present practice within the context of a general education which, we believe, is as vital at this stage as in the earlier years of the grammar school. In the evidence we have received there is a general agreement that Advanced level courses, as taught and examined at present, are too highly specialised and that they both overburden and constrict the curriculum of the pupils. What the educational system is now asking of sixth form pupils is that they should absorb and reproduce as many facts, skills and techniques as possible within their chosen specialist subjects. This is at a time when numbers in the sixth form are increasing year by year*, competition for entry to universities is severe, and the academic and intellectual energies of the average pupil are very largely preoccupied in keeping up with the pace and volume of specialist work.

We sent a questionnaire to all grammar schools and schools with grammar streams in Wales to investigate the present pattern of studies in the sixth form and to discover how far pupils were engaged in studies outside their specialist fields. The results showed that 20 per cent of all pupils in the sixth form take only one or two subjects at Advanced level. Of those taking three Advanced level subjects, 54 per cent offer science groups and 46 per cent offer arts or mixed groups. The pendulum has swung and the science sixth is now numerically stronger than the arts sixth.

Table 6.1 The Place of the Arts Subjects in the Science Sixth

	Number of Periods per Week														
	None			One			Two			Three			Four or more		
Type of School	B	G	M	B	G	M	B	G	M	B	G	M	B	G	M
Number of Schools	7	5	36	2	4	6	7	5	21	1	5	10	9	10	21
% of Total	32%			8%			22%			10%			27%		

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* Amongst maintained grammar school pupils the proportion of 17-year-olds still in school rose from 30 to 44 per cent over the last six years.

Table 6.1 shows the numbers of boys', girls' and mixed schools, and the percentage of schools providing courses in arts subjects (excluding preparation for the 'Use of English' paper) for sixth form pupils specialising in mathematics and/or science. It will be seen that about one-third of the schools make no provision at all and nearly three-quarters either make no provision or give less than four periods a week. Of the 101 schools which give the science sixth some experience of arts subjects, 56 include current affairs or social studies among the list of subjects offered. Relatively few offer a foreign language—French (11), German (10) and Russian(3)—and they appear to devote little time to it, in some cases only one period a week. Music, art appreciation, scripture, history, geography, philosophy and economics are among the other subjects mentioned. Many of the replies show that Religious Instruction has been included—usually one period. In those schools which do not mention it, we have to assume that the subject is not taken at this level.

Table 6.2 The Place of Science in the Arts Sixth

	Number of Periods per Week														
	None			One			Two			Three			Four or more		
Type of School	B	G	M	B	G	M	B	G	M	B	G	M	B	G	M
Number of Schools	11	15	56	4	4	10	7	6	15	0	1	3	6	5	4
% of Total	56%			12%			19%			3%			10%		

Table 6.2 shows the numbers of boys', girls' and mixed schools, and the percentage of schools, providing courses in science for sixth form pupils specialising on the arts side. It will be seen that 56 per cent of the schools make no provision at all and 90 per cent either make no provision or give less than four periods a week. A small number of the schools included in the last column offer General Certificate of Education Ordinary level subjects—biology, human biology or geology—to some arts pupils. Of the 65 schools providing science for the arts sixth, 13 offer a course in the history and philosophy of science, and four a review of modern science while the remainder give courses in general science, biology, human biology, pre-nursing, physics and chemistry. The main emphasis is on biological rather than on physical science.

Clearly, there is room for experiment in devising suitable science courses for non-specialists in the sixth form and the success of such courses will depend very largely upon the enthusiasm and interest of individual teachers. We believe that the work, if possible, should not be confined to one branch of science, neither should it be limited to the history and philosophy of science. A series of individual projects, each involving some experimental or field study work, has much to commend it.

It is apparent from the replies to our questionnaire that complementary studies in the sixth form are not at present making an adequate contribution to the general education of the pupils. While there is in the schools a growing concern for the need to widen the horizons and develop the interests of their pupils outside their specialist fields, the use made of minority time still tends to be haphazard and the number of periods given to it is in most cases inadequate. We recommend that the time allowance for specialist subjects should be about two-thirds of the total teaching time. It should be made clear, however, that our recommendation presupposes substantial reductions of examination syllabuses, particularly in the growing science subjects. Moreover, there should be adequate time for private study and improved laboratory facilities for effective practical work in science to make the best use of the available time (see Chapter VII).

Some of the difficulties confronting the schools in providing minority time courses have been mentioned earlier. The pressures on the sixth form, with its increased numbers, have come to the point where a better balanced curriculum can be generally achieved only if the present factual and memory content of Advanced level courses is lessened. The competition for entry to universities and the consequent emphasis on high marks in the Advanced level examinations, together with larger teaching groups, have too often resulted in excessive preoccupation with the specialist subject syllabus and memorisation at the expense of broader study and reflection. Another factor which militates against minority time, and one that has been stressed to us in much of the evidence, is shortage of well-qualified staff. This is particularly so in science and it is increasingly difficult for schools to secure those who are able and willing to devise suitable courses which will hold the interest of the non-specialist.

To allow the work of the sixth form to advance on a broader front, there must be a lightening of syllabuses, improvements in staffing and accommodation, and a better understanding between the schools and universities of each other's needs and problems. Freed from some of the existing pressures, the schools will need to reconsider ways of providing a liberal education in the sixth form. We are of the opinion that, at present, the non-specialist work is frequently lacking in organisation, purpose and coherent pattern. Excessive specialisation cannot be counter-balanced by a superimposed structure of 'general studies' conceived mainly as a fringe of other subjects, arbitrarily chosen on the basis of difference, given a token allotment of time, and taught *in vacuo*.

A liberal education in the sixth form depends upon an enlightened approach to specialist subjects together with well-directed study in other, equally important, fields. Firstly, specialist subjects themselves, which stem from and are centred around the pupils' primary interests, should be a vehicle for a liberal education. Unfortunately, as they are now taught and examined they contribute to what Whitehead called 'a celibacy of the intellect which is divorced from the concrete contemplation of the complete facts'. In *Science and the Modern World* he foresaw the incompleteness and polarisation of a professional education. 'There is something between the gross specialised values of the mere practical man and the thin specialised values of the mere scholar. Both types have missed something; and if you add together the two sets of values, you do not obtain the missing elements. When you understand all about the sun and all about the atmosphere and all about the rotation of the earth, you may still miss the radiance of the sunset. There is no substitute for the direct perception of the concrete achievement of a thing in its actuality.'

Ideally, then, it is suggested that specialist subjects should be studied and examined in the context of a liberal education. To achieve this, syllabuses should have their factual content reduced and examinations at the Advanced level should be a test not so much of skills and intellectual techniques as of critical habits of mind and the exercise of judgment. Such an approach would make greater demands on sixth form teachers but we believe that, if syllabuses can be modified along these lines, the challenge will be met.

The recasting of specialist subjects, on the lines suggested, could contribute in very large measure to a more liberal spirit in the sixth form but, to complete the task, complementary studies are also necessary. Each intellectual study or associated group of studies has its own mode of thinking and fields of experience. A sixth former should, therefore, be given the opportunity to gain some appreciation of, and sympathy with, modes of thought and experiences in a field of study other than, but as important as, his own specialist subjects. To be effective, such complementary studies require careful organisation and an adequate allocation of time. In order to create a community of interest in the sixth form which would over-ride the traditional division into arts and science sides, it is desirable that the two groups should be brought together for some serious common study. These periods should be blocked on the timetable so that all pupils can attend. The resources of the school library should be used to the full and written work should be an essential feature.

At this point we must note the general concern, at all levels from primary school to university, at the low standard of written and spoken English; this seriously affects not only balance in education, but communication in science and technology. The reasons for the present situation are no doubt complex and indeed could be regarded as sufficiently important to require a separate investigation.

In the evidence we have received there is almost unanimous opposition to proposals for the external examination of minority time work. At present, the majority of schools are still feeling their way; variety, individuality and freedom to experiment are the very essence of general studies, and we believe that the educational arguments against their external examination outweigh the suggestion that only those subjects which are examined are seriously studied.

A school is an active society of young persons and the effect of school societies and other extra-curricular activities on general education must not be underestimated. Participating in voluntary activities of this kind—dramatic and debating societies, choirs, orchestras, art and craft groups, science clubs and the like—would be encouraged and vitalised by purposeful use of minority time.

It is important that there should also be provision for all pupils to have some instruction in preparation for adult life, including the discussion of such topics as work, leisure, personal relationships and family life, citizenship and service to the community.

6.2 Mathematics

6.2.1 *The Present Situation*

The number of pupils taking mathematics at the Advanced level of the General Certificate of Education has strikingly increased over the last ten years. The rate of increase can be clearly seen from the following table which shows the number of candidates examined by the Welsh Joint Education Committee in mathematics at the Advanced level at intervals from 1951 to 1962.

Table (a) gives the figures for both boys and girls, Table (b) for boys only and Table (c) for girls only.

Table 6.3 Numbers of Candidates taking Mathematics at the Advanced Level

	1951	1955	1959	1960	1961	1962	% $\frac{1962}{1951}$
(a): *Boys and Girls*							
P and A Mathematics	470	580	906	1,003	1.068	1,113	236.9
Pure Mathematics	191	238	428	505	472	492	257.6
Applied Mathematics	118	177	325	395	368	364	308.4
(b): *Boys only*							
P and A Mathematics	423	511	780	868	918	946	223.6
Pure Mathematics	158	190	352	421	272	394	249.3
Applied Mathematics	97	142	278	339	295	303	312.3
(c): *Girls only*							
P and A Mathematics	47	69	126	135	150	167	355·3
Pure Mathematics	33	48	76	84	100	98	296·9
Applied Mathematics	21	35	47	56	73	61	290·5

The figures in Table 6.3 show that the combined subject of Pure and Applied Mathematics is still being taken by most of the candidates, although allowances should be made for the fact that the numbers include pupils who subsequently also take examinations in the separate subjects. The majority of pupils are taking mathematics at Advanced level because they believe, rightly, that a knowledge of the subject is essential for the successful study of scientific and technological subjects. The number of pupils who will eventually study mathematics for an honours degree is relatively small, and it so happens that these are generally in the group who take the two separate subjects Pure Mathematics and Applied Mathematics in the sixth form. This is perhaps due to the wide-spread belief that this combination is a requirement for entry to an honours degree course in mathematics. This belief involves the serious disadvantage that pupils may have to decide at 16 years of age whether to embark on a course leading ultimately to an honours degree in mathematics. This conflicts with our considered view that specialisation should not take place too early, and that it is important to provide an education in the sixth form which will allow as many doors as possible to remain open into higher education.

Strong criticisms have been levelled at the content of existing syllabuses and we note with satisfaction that changes are being considered. In Pure Mathematics the omission of new concepts and some modern developments has merited criticism. In Applied Mathematics the limitation of the work to hydrostatics, statics and dynamics, coupled with traditional examination papers in which there is considerable emphasis on manipulative dexterity, has led to a situation in which important physical principles are obscured. Many pupils taking this subject in school find themselves inadequately prepared to study applied mathematics and physics at the university. In the combined subject of Pure and Applied Mathematics there has been strong criticism of the lack of mathematical rigour and the rather superficial treatment of many topics, particularly in mechanics. This makes the present combined subject unsuitable as a preparation for university work in mathematics and not even a good background for work in those branches of science which require for their proper understanding a sound knowledge of mathematics.

Further, it is worth noting another unsatisfactory feature, namely the use of the combined paper as a diagnostic test taken at the end of the first year in the sixth form. It appears that successful candidates are then encouraged to proceed to a study of the separate subjects, but in view of the nature of the Pure and Applied Mathematics paper a more rigorous, progressive course from the beginning would be preferable. On the other hand, failure leads to a repetition of the same work and therefore a lack of progression in the mathematics course. We are most strongly of the opinion that the present single subject of Pure and Applied Mathematics has long outlived its usefulness and should be abolished.

It is clear that a revision of syllabuses and a recasting of the existing pattern of work in sixth form mathematics are called for.

6.2.2 *Suggested Changes*

Various proposals for a less complicated pattern of examination subjects have been made to us. It is, indeed, difficult to justify a situation in which, alone in the curriculum of the sixth form, mathematics needs to be examined as three separate subjects. This situation appears to offer unnecessary difficulties to the schools in organising sixth form mathematics courses.

A suggestion submitted in evidence to us, and attractive in its simplicity, is that all the present Advanced level papers in mathematics, except that in Pure Mathematics, should be discontinued. We are favourably impressed with this view and are of the opinion that pupils wishing to take mathematics in the sixth form should study pure mathematics, examined as one single subject. Pure mathematics must be regarded as an independent discipline and studied for its own sake. It is when it is regarded in this way that it achieves its greatest value for physics and other branches of science requiring for their study a knowledge of mathematics. Attempts to devise special syllabuses in pure mathematics for physicists, engineers, etc. do not deserve to be encouraged. They are the results of premature decisions on what is likely to be useful and what is not.

The physical content of an applied mathematics course often fits more appropriately into a physics course and the mathematical content into a pure mathematics course. Work in the subject in school should not run parallel with physics and pure mathematics, but should follow a training in both. We recommend, therefore, that work in this subject is best undertaken in the university and that the Advanced level subject 'Applied Mathematics' should be abolished.

It is generally believed, however, that there is a small minority of pupils whose dedication to mathematics becomes clear at an early age. Their interest in the subject is so strong that they would become dissatisfied with the level of attainment required by the single subject—Pure Mathematics. It has indeed been put to us that the continued existence of mathematics as a subject in its own right will rest generally in the hands of such students. They are the future mathematicians on whom we shall depend for major advances in our mathematical knowledge. For such pupils it has been suggested that a second mathematics subject of a much more advanced nature should be provided.

This provision would cause some difficulties to schools which would then be called upon to decide which pupils were capable of undertaking work at this level; there is a risk of unsuitable pupils being permitted to attempt this higher level work. We are not generally in favour of a situation in which mathematics alone among Advanced level subjects should involve such a high degree of specialisation in the sixth form. It conflicts strongly with the principles of balance in education and the need to postpone specialisation as late as possible. There are many advantages in encouraging the future mathematician to take as broad a course as possible in the sixth form and groupings of subjects which involve pure mathematics, physics and an arts subject have much to commend them.

It is not within our terms of reference to consider details of syllabuses. We welcome experiments which are now going on, in parts of Wales and elsewhere, to devise new syllabuses, but we also believe that it is only after considerable experience of teaching new topics that these should be allowed generally to displace more traditional material. When revision is undertaken, however, it may well be that, with the great increase in the last decade in numbers taking mathematics at the Advanced level, it will be possible to devise alternative sections to the single-subject-mathematics syllabus. While much of the work involving fundamental principles will remain common to all, there is room for choice in selecting fields in which such principles find applications.

In any review of this kind it should be constantly borne in mind that the teacher is the lynch pin in the work of the schools. Although teachers have to conform to examination requirements at certain stages, they enjoy considerable freedom in their own method of teaching, in interpreting syllabuses and in choice and sequence of work. We hope that they will play a more positive role in research and experimental work and that more of them will have the initiative to submit examination syllabuses of their own for consideration by the Examining Bodies. Many however work in relative isolation, gaining sustenance from text-books, old question papers and some general mathematical reading; they may feel a little vulnerable on their own and need to get together much more frequently to be informed of recent developments and meet others who face the same problems as they do. The need for courses and conferences is greater than ever; many of the teachers have had little or no experience in teaching 'modern' mathematics; this is not surprising because much of it has only gained prominence within the last decade or so. Thus, all but the most recent recruits to teaching need also to learn more about the new concepts in mathematics: it will only then be possible for them to decide on the extent to which the new ideas can with advantage permeate the schools.

The obvious need of courses for the learning of the 'new mathematics', as well as for the discussion of developments, will have to be met by local education authorities, teacher organisations and associations, faculties of education and by the Ministry of Education. A few courses of this kind have already been provided in Wales but we believe that there is need of many more if there is to be a major overall shift in mathematical opinion. It should not be inferred from this that a major change is of necessity desirable. What is desirable is that the teachers, by and large, should have the opportunity of becoming better informed about developments in their own subject.

More literature, too, relating to experiments carried out by the School Mathematics Project Group in England and by various groups in the United States of America and other parts of the world should be made available and studied with care. The O.E.E.C. publications, for example, merit wider currency. There are other growing points which might interest the mathematics teacher; for example, films, television and teaching machines—some of these may become as indispensable in future as the text-book is today.

6.3 Science

The replies to our questionnaire to all grammar schools and schools with grammar streams in Wales showed that, of all pupils in the sixth form taking three subjects at the Advanced level, 54 per cent offer science and mathematics subjects.

The combinations of science subjects, within this proportion of 54 per cent, are as follows:

A. Physics, Chemistry, Mathematics	22 per cent
B. Physics, Chemistry and one Biological subject	12 per cent
C. Physics, Pure Mathematics, Applied Mathematics	11 per cent
D. Two Biological subjects and a Physical Science or Mathematics	9 per cent

In Group A the great majority of pupils take the combined Pure and Applied Mathematics subject whilst in Group D the physical science is normally chemistry.

The table in Appendix I shows the numbers of candidates examined by the Welsh Joint Education Committee in science subjects at the Advanced level of the General Certificate of Education at intervals from 1951 to 1962.

These figures show that the percentage increase in the number of candidates in the physical sciences has been greater among the girls, but the boys still make up about four-fifths of the total. Physics is slightly more popular than chemistry with the boys, whilst the reverse is the case with the girls. Geology is also attracting more candidates. In 1951 and 1955 biology attracted more candidates amongst the boys than zoology and botany; more recently, however, the trend has been towards the latter subjects. With the girls, biology has always attracted fewer candidates than zoology and botany. Over the last ten years there has been a marked swing to the physical sciences. The proportion of girls on the arts side is still greater but it will be seen from these figures that there are now fewer boys taking English and French than there were ten years ago.

There is a widely held view that a small proportion of girls take science because the facilities for science available in the majority of girls' schools are not as good as they are in boys' or mixed schools. However, the replies to our grammar school questionnaire show clearly that this is not so. The proportion of girls taking science in girls' schools is, in fact, about 25 per cent higher than in mixed schools where facilities are available which attract a high proportion of the boys (as shown in Table 8.2). This is in face of the greater difficulty experienced by girls' schools in recruiting well-qualified staff in mathematics and science. We are, therefore, led to the conclusion that in mixed schools girls tend much more to think that mathematics and science subjects are the preserve of the boys and that the climate of opinion is therefore less favourable to science than it is in girls' schools.

We have already stated our opinion that in the sixth form a degree of specialisation claiming more than about two-thirds of a pupil's time should be discouraged. Three subjects, each receiving seven or eight periods a week and taken to the Advanced level of the General Certificate of Education, would thus be taken by the sixth form pupil aiming at entry to university or equivalent institution.

However, the big increase in the number of pupils entering the sixth form, some of whom do not wish to pursue university studies, makes it necessary to think of alternative courses. Our questionnaire revealed that even now 20 per cent of all pupils in the sixth form take only one or two subjects at the Advanced level. This proportion is likely to increase over the next decade and the schools will need to devise coherent courses around the one or two Advanced level subjects taken. The remainder of the pupils' time could be devoted to additional science subjects at the Ordinary level and to other subjects. The successful completion of such courses leads into institutions of higher education other than the university.

There is a tendency to underestimate the importance of a mathematical background in science courses other than physics in the sixth form. We recommend that all pupils taking a science subject, but not mathematics, at the Advanced level should follow a course of mathematics such as, for example, the Ordinary level course in Additional Mathematics.

The replies to our questionnaire show that about 40 per cent of the pupils in the science sixth take courses which include one or more Advanced level biological subjects. Of these, rather more than half also take physics and chemistry, usually without mathematics: the remainder study botany and zoology, often because of lack of interest in, or aptitude for, mathematics and physical science. This dislike of anything savouring of mathematics is so strong with some pupils that they elect to study a non-science subject with botany and zoology. There has, too, been an impression in the schools that university faculties require the separate subjects botany and zoology in preference to biology for exemption from the intermediate stage of degree courses in biological subjects.

This traditional pattern of work in the schools is criticised in much of the evidence submitted to the Council. It is claimed that many pupils now enter the university departments of biology with an inadequate background knowledge of mathematics and physical science. The division of biology into two branches taken as separate Advanced level subjects is deprecated on the grounds that, apart from being artificial and actually harmful at this level, it restricts the time available for the study of mathematics or physics and chemistry. At a time when the unity of the subject should be emphasised and relationships sought with other branches of science, the work has in fact become narrow and restrictive, and does not now form a good basis for advanced work in fields of modern biology which depend heavily on physical and chemical techniques and principles.

We are of the firm opinion that specialist work in the sixth form should emphasise fundamental studies on a broad rather than narrow front. Fragmented and over-specialised courses should have no place at this level; they often act as a brake on later development. This is particularly true of the science sixth where each of the main subjects studied should have value, not as a pre-eminent specialism, but as a component in a basic scientific education.

The evidence received suggests that the separate subjects of Botany and Zoology have outlived their usefulness in the school curriculum and might well be replaced by a single subject, Biology. We would emphasise that the new course should not consist of simplified versions of the present botany, zoology and biology syllabuses, but should attempt to be a true synthesis of the biological sciences, stressing the themes which underlie them all. For this reason we welcome attempts, such as that contained in the University of Birmingham Gulbenkian Report (1959), to devise new syllabuses. There must be a recognition, too, that the syllabuses in mathematics and the physical sciences must in some measure provide for the interests of students of biology or geology. For example, statistics is a branch of pure mathematics which, if included in the mathematics syllabus, would be of advantage to the biologist who takes Advanced level mathematics. It is clearly necessary to ensure, as already emphasised in the foregoing chapter, that all pupils of grammar school calibre should study mathematics and the physical sciences up to the end of the fifth form. It is more important indeed for the future biologist to have taken mathematics, physics and chemistry at this stage than to have passed in Ordinary level biology. This also applies in the case of future geologists.

6.4 University Entrance Requirements

In general, the groupings of subjects often asked for by university faculties are meant to form related educational schemes. It is clear, however, from the evidence we have received that the diversity of these requirements often causes difficulties and misunderstandings in the schools. In consequence, it happens not infrequently that the choice of an honours subject at a particular university has virtually to be made by the pupil at the age of about 16, which is a degree of specialisation that is educationally indefensible. Moreover, it is our considered opinion that greater flexibility in faculty requirements would be to the advantage of both the schools and the universities. We believe, also, that it should always be possible for the able student, if he wishes, to take an honours course in a subject for which he did not sit at the Advanced level. On the other hand, we recognise that there is virtue in a variety of approach to academic subjects in the universities themselves and we would regard any attempt to introduce uniform schemes as detrimental to the development of a broad range of scholarship.

6.5 Syllabuses and Examinations

In this section, we have for convenience included a consideration of syllabuses and examinations at both the Ordinary and the Advanced levels.

6.5.1 *Syllabuses*

In evidence we have received there is a general and emphatic demand for a drastic revision of syllabuses in science and mathematics, both at the Ordinary and at the Advanced levels. Existing syllabuses contain material that is relatively easy to examine and hence many questions call largely for the reproduction of memorised facts. In science this has played a large part in bringing about a serious deterioration in the teaching of scientific method—the inculcation of habits of careful inquiry, practice in the use of the inductive approach, the consideration of evidence and the testing of hypotheses.

Scientific discovery and its applications to the problems of everyday life have advanced further and faster in the twentieth century than ever before, but the present syllabuses in science are very much what they were 50 years ago. Many of the topics are out-of-date and unrelated to the world in which pupils now live. In an age of space travel and plastics, pupils spend too much time on tedious geometrical optics, specific gravity determination, and the properties of compounds of metals which have little significance for them. Some additional material has been added, such as a small amount on atomic structure, valency theory and electronics, and a few topics have been taken out, but such changes have been made without due consideration of their effects on the formative aspects of science teaching, or on the co-ordination of one subject with another.

The current awareness of the defects in school science syllabuses has led to a widespread demand for change. The Association for Science Education has taken a welcome initiative in this country and produced new syllabuses; similar efforts are being made in the United States of America and elsewhere.

In framing new syllabuses the following considerations need to be borne in mind:

(a) The choice of content in each of the three branches should be appropriate to all pupils who study science up to G.C.E. Ordinary level; it should be as suitable for pupils who leave at 16 as for those who will study science beyond the age of 16; special syllabuses in the fundamental branches of science are preferable to proliferated subjects to which we referred earlier in Chapter V.

(b) The Advanced level syllabus must serve as a preparation not only for the future specialist in that subject but also for the many others who need the subject as an ancillary.

(c) The syllabus must be brought up-to-date in respect of theory and illustrative topics.

(d) Enough of the work must admit of being taught in a way that throws the pupil on to his own resources, and gives him at first hand the experience of scientific method.

An examination of many existing syllabuses shows that they are seriously deficient in meeting the conditions set out in the foregoing paragraph. A great deal of thought and discussion needs to be given to the means of finding an adequate experimental basis for modern theory, particularly in atomic structure, which now forms a background to the teaching of physics and chemistry even at the Ordinary level. Research into the teaching of science, already started by the Nuffield Foundation and other bodies, needs to be maintained continuously, so that school work keeps pace with the rapidly changing state of scientific knowledge. It is gratifying to note that some initiative in this direction has been taken by individuals; they need every encouragement and financial support.

Grammar schools have become increasingly aware of the unsuitability of traditional work in physics, chemistry and biology for some of their pupils. Hence the introduction of such 'new' science subjects as engineering science, agricultural science, horticultural science and human biology, to which we have already drawn attention in Chapter V. The growth in demand for such subjects is an expression of the almost self evident fact that children's interests differ widely, and that one syllabus in each of the subjects, chemistry, physics, and biology, cannot be expected to meet all needs. The very big increase in the number of pupils sitting General Certificate of Education Ordinary level examinations has made it possible to consider offering alternative syllabuses in science subjects, to meet the obvious fact that all pupils do not have the same interest or live in the same environment. Is it not possible to give a girl an adequate scientific education through a course in science which includes the chemistry of foods instead of such topics as the preparation and properties of the compounds of metals? Could not a boy from an industrial area derive benefit from studying the chemistry of fuels, perhaps with reference to a consideration of energy and its relation to machines in a physics course? Is it not possible to devise work in microbiology and ecology which is as valuable a part of scientific education as the morphological study of types? Such alternative syllabuses in a particular subject must satisfy the essential conditions we have listed above. They would undoubtedly have a common area of content in each subject and would be examined in a paper in which a common compulsory section was followed by a series of alternative sections.

The need for a revision of the syllabus in mathematics at the Ordinary level has already been stated in earlier sections. The amount of formal geometry taught is still great and far too much time is spent on purely manipulative arithmetic and algebra. We consider, also, that it is time that elementary statistics should form part of a school mathematics course.

The question of the desirability of replacing some of the traditional mathematics, now being taught in grammar schools, by 'modern' mathematics is one of the most relevant to the mathematics teacher and it is a point that we considered earlier in the chapter. The reasons for its introduction have been put forward by numerous bodies and individuals in reports that are easily available. There is no doubt that there is a need for further thinking of a fundamental nature about the content of mathematical courses which should be closely linked with practical experimentation in the classroom.

If such a change comes, additional problems will arise in the schools. Many teachers, especially those who graduated some 25–30 years ago, admit that their knowledge of the subject is inadequate for the teaching of it, even at school level. Many will have to 're-learn' the subject. The situation is not eased by the fact that many of these teachers are the ones who are already bearing the main burden of sixth form teaching. Furthermore, the introduction of 'modern' mathematics would inevitably mean a change in the content of the Advanced level syllabus. This should be gradual and, for a transition period at least, the papers set should be alternative ones. At present there is a scarcity of text books suitable for schools. We look forward with interest to the results of experiments such as those of Professor Thwaites and others.

The Third Report of the Secondary School Examinations Council (September, 1960) drew attention to the urgent need to reduce the pressure on sixth forms by a reduction in syllabuses. The report states that (p. 3) . . . 'there is a wide-spread feeling that, as the pressures intensify and the sheer volume of knowledge mounts up, syllabuses are becoming more and more over-loaded, particularly but not only in science subjects, and specialisation is thus tending to increase to a still more harmful degree.' Following on the report, the Minister of Education's Circular 9/61 (12th May, 1961) urged Examining Bodies to revise and reduce their syllabuses.

However, we have received evidence that the Welsh Joint Education Committee's subject panels, in common with those of the other Examining Bodies, have hitherto been unable to bring about a substantial reduction in syllabuses.

This problem is vital and we are concerned that so little has been achieved to remedy a situation in which the schools are being increasingly over-burdened. If the existing subject panel system is ineffective in bringing about a reduction in the factual content of syllabuses, we would urge that some alternative machinery be considered.

6.5.2 *Examinations*

Few countries appear to attach such importance to examination records, from the 11 plus to the class of the degree, as Britain. It is still not fully appreciated that an external examination system to a very large extent controls the nature of the work done in the schools. It is undeniable that most teachers teach for the examination. Facts are emphasised; generalisations are studied as aids to memory rather than as a result of inductive processes. The choice of facts may change but the factual type of examination paper continues. Text books are written with examinations in mind; pupils and teachers follow them closely for examination results; so the wheel turns.

A pass or failure in the external assessment of a subject bears the stamp of finality and is too often regarded as the sole criterion of success. This is in face of such salutary warnings as that given by the secretary of one of the Examining Bodies—'the examination verdict is an assessment of part only of the candidate's school career and only a partial assessment of his capacity.'*

It is regrettable, but understandable, that changes in school attitudes are most readily brought about by changes in examination procedure. It is envisaged that the new examinations for the Certificate of Secondary Education will be generally introduced by the summer of 1965. As they will be designed for a much greater number of pupils, they will become applicable to all types of secondary schools in Wales. In view of the considerable body of evidence that we have received criticising the effects of examination pressure on a broad and balanced education in the schools, we feel considerable misgiving about the advent of new examinations unless they are administered and conducted in such a way that they stimulate and do not shackle the pupils' day-to-day work in the schools.

These new examinations may offer schools greater opportunities in the future of broadening their range of differentiation in both content and method. The schools themselves may exercise greater control over syllabuses and marking and it is hoped that a number will take advantage of the freedom that may be theirs if they venture away from the external regional examination and offer syllabuses of their own instead. It is also to be hoped that the various local education authorities and the teachers in particular will think very carefully about the function of examinations in the life of a school, while there is still time and before any new machinery is set in motion; it may be too late when this machinery has developed a momentum difficult to change.

The attitude of individual teachers towards practical work in science is largely influenced by the kind of examination taken by their pupils. Much thought needs to be given to the technique of carrying out practical examinations. The present Advanced level examination imposes an undesirable pattern on the work of the schools. Experiments are devised to fit into packets of time that suit the examination. The solution of a problem, the inquiry into a natural phenomenon, which are of the very essence of science, are now actively discouraged by the type of examinations set. It is our opinion that methods should be devised for the assessment of a pupil's practical work over the whole of his course rather than in the artificial conditions of a single examination limited to an hour or so at the end of it. Indeed, we believe that the assessment in general of a pupil's progress and achievements should increasingly become the responsibility of his teachers, who alone have the opportunity to know his all-round capabilities and are, therefore, best fitted to make a judgment.

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* Dr. Petch, *Fifty Years of Examining*. 1953.

6.6 Summary

Non-specialist studies in the sixth form are not at present making an adequate contribution to the general education of the pupils. We recommend that the time allowance for specialist subjects, including practical work and private study, should be not more than two-thirds of the total teaching time.

A better balanced curriculum can be generally achieved only through a lightening of syllabuses, improvements in staffing and a better understanding between the schools and universities of each other's needs and problems.

Variety, individuality and freedom to experiment are the very essence of minority time work and we would, therefore, oppose any proposal to examine such work externally.

We consider that the combined subject of Pure and Applied Mathematics should be abolished.

We recommend that mathematics in the sixth form should be studied and examined as one single subject, Pure Mathematics. Applied Mathematics is more appropriately studied at university level.

Since it is vital that the practising teacher should play an active part in any revision of mathematics syllabuses, he should have more opportunities, through courses and conferences, of becoming better informed about developments in mathematics.

The proportion of girls in girls' schools taking science at the Advanced level is higher than that in mixed schools where, we believe, the climate of opinion is less favourable for girls to take science.

There is a tendency to underestimate the importance of mathematics in sixth form courses in the life sciences. We recommend that all pupils taking a science subject, but not mathematics, at the Advanced level should follow a course of mathematics such as, for example, the Ordinary level course in Additional Mathematics.

Specialist work in the sixth form should emphasise fundamental studies on a broad rather than narrow front, and in the science sixth each of the main subjects studied should have value, not as a pre-eminent specialism, but as a component in a general scientific education.

Evidence indicates that the separate subjects of Botany and Zoology have outlived their usefulness in the school curriculum and might be replaced by a single subject, Biology. This subject should be different in content and emphasis from the present subject called Biology.

Freedom in the choice of subjects in the sixth form is an essential part of a broad education but it can only be achieved if it is not impaired by university faculty requirements. At present it is restricted by entry requirements in some universities relating to groups of subjects. We deplore this and would urge that there should be much greater freedom in a student's choice of subjects.

We are concerned that so little has been achieved in the revision and reduction of syllabuses. If the existing subject panel system of the Examining Bodies is ineffective in bringing this about, we would urge that some alternative machinery be considered.

It is still not fully appreciated that an external examination system to a very large extent controls the nature of the work done in the schools. As changes in school attitudes are most readily brought about by changes in examination procedure, we recommend that urgent attention should be paid to the nature and scope of examinations.

Chapter VII

STAFFING, ACCOMMODATION AND EQUIPMENT

7.1 Introduction

Science, to an extent greater probably than any other subject in the curriculum, demands adequate resources for successful teaching. Not only is it necessary to have teachers with a sound knowledge of their subject, but they need to be skilled in the techniques of presentation and supported by facilities for practical work by the pupils and demonstration experiments by the teacher. Opportunities must be provided to exploit new teaching aids as they become available. This in turn requires well planned laboratories, lecture rooms and equipment, all of which have to be maintained in a state of readiness by experienced auxiliary staff.

Much of the evidence given to the Council presented a disturbing picture of shortages of accommodation and equipment, and, above all, of qualified staff. Evidence from sources close to the work of the schools repeatedly suggested that inability to recruit suitably qualified teachers for senior posts and a high rate of turnover amongst the more junior teachers were the major factors impeding the attainment of high standards of work in science. The position in mathematics appears to be even more disturbing, We decided therefore to obtain the statistical information necessary to assess the situation with some accuracy before considering possible means by which it might be rectified. Returns were obtained (1961–62) from a very high proportion of the secondary schools of Wales, giving information concerning the qualifications of staff employed in the teaching of science and mathematics.

It should be stated that this statistical survey was made in the full realisation that the level of academic attainment is not the only factor in determining the quality of an individual's teaching. In the sixth form of a grammar school, however, the standard of the specialist work in any given subject in general demands a teacher who has a university degree (or its equivalent) in that subject, probably at honours level. It is also important to realise that at all stages the gifted child requires the stimulus of contact with first class minds. There are in the schools many teachers who do not hold high honours degrees but who are teaching science and mathematics effectively and with enthusiasm. At the same time, it would appear generally true that the teacher with the higher academic attainment is likely to be the more effective in teaching his subject in the sixth form. We believe, therefore, that our survey, which had of necessity to be restricted to the factual details of academic qualifications, is valid in assessing the staffing position in secondary schools in science and mathematics.

7.2 Staffing in Schools Providing G.C.E. Courses in Mathematics and the Main Science Subjects

Table I in Appendix II summarises the information received from 154 schools, with totals of 4,272 members of staff and 84,675 pupils. The grammar schools range in size from 175 pupils (9 staff) to 891 pupils (45 staff) whilst

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the comprehensive schools vary from 500 pupils (25 staff) to 1,500 pupils (71 staff). Three out of every five heads of these schools are arts graduates, but the proportion is very much higher in the areas of two local education authorities where 100 per cent and 82 per cent respectively are arts graduates. The information collected in Table 1 was obtained on a subject basis; that is, each school was asked to supply the qualifications of each member of the staff teaching mathematics or a science subject. In some schools a teacher is responsible for more than one subject and his qualifications in both subjects may be at different levels. The total of 1,748 'teachers' in Table 1 is therefore higher than the real number of teachers. This is 1,277 for the schools involved and represents 29.9 per cent of their total teaching force. Thus, in these schools, nearly one in three teachers is involved in the teaching of science and mathematics, although some of them may also spend some time teaching other subjects.

Information was also obtained on the age distribution of teachers of mathematics, physics and chemistry in relation to their qualifications. In order to compare with a corresponding arts subject, similar facts were obtained on a sample basis for teachers of English. The histograms in Fig. 7.1 show the position for each category of teacher.

In the subjects with which we are concerned it is clear from comparisons of the age group that the schools continue to attract about the same number of honours graduates as in pre-war days. It must be remembered that the increase in the number of pupils now in the schools is making progressively heavier demands on staff and this increase is being met, not by an increase in the number of honours graduates, but by the employment of graduates with pass degrees and others with a variety of qualifications, some of which cannot be regarded as satisfactory. Thus it is alarming to find that in mathematics, in the younger age group, there are now twice as many teachers with pass degrees as with honours degrees, and that the number of non-graduates exceeds the number of honours graduates. Fewer than one in three of the younger teachers of mathematics holds an honours degree in the subject.

This progressive decline in the academic quality of the younger teacher of science and mathematics is the most serious problem affecting the teaching of these subjects in the schools of Wales. Unless the trend can be drastically reversed there can be little expectation of the maintenance of present standards, let alone the progressive improvement which is called for in much of the evidence submitted to the Council. This matter is referred to later in this Report, where an attempt is made to assess the number of teachers required in relation to the output of the University and its Departments of Education.

An analysis of the class of honours degree, a summary of which is shown in Table 2 of Appendix II, shows the unfavourable position of science and mathematics when compared with English. Whereas 75 per cent of the teachers of mathematics have only third class honours or lower qualifications, only 34 per cent of the teachers of English are in this category. The corresponding figures for chemistry and physics are 48 per cent and 59 per cent respectively. It is noteworthy that the percentages of graduates with good honours degrees are greater in the older age groups. In this context it should be noted that 6·8 per cent of the teachers in Wales are over 60 years of age compared with 3 per cent for England and Wales. Special mention must be made, too, of the position of General Science, where 62 per cent of the teachers hold third class honours or lower qualifications. This is regrettable in that it is this subject which generally gives a pupil at the secondary stage his first impressions of science. Teaching which is not stimulating and effective in the early years may well make the subject distasteful to pupils who might otherwise have been attracted towards science. At best, unsatisfactory teaching at this level will fail to lay secure foundations for further work. In many schools the subject of General Science represents the only contact many arts pupils have with scientific knowledge. Badly taught, the subject is likely to widen the gulf between the 'two cultures'.

It cannot be assumed that the less well-qualified teachers are to be found only among those who are occupying junior positions and working under the guidance and supervision of a senior member of staff. Table 3 of Appendix II gives the qualifications of teachers who are heads of departments or otherwise responsible for organising the subject in a school. Of the 154 schools from which returns were received, all purported to offer mathematics but there were two which did not offer physics and two which did not offer chemistry. The word 'purport' is used with intent. *There are five schools which have no graduate mathematics teacher; seven schools with no graduate teacher in physics; two schools without a graduate teacher in chemistry; and the position is equally serious in the biological sciences. Many schools are dependent on teachers with less than five years' experience to organise a science subject throughout the school: 27 per cent of physics heads of departments, and 30 per cent of biology heads are relatively inexperienced.* In some cases, in bilateral and comprehensive schools, the duties also included supervision of courses for 'modern' pupils.

Comment must be made, too, on the peculiar array of qualifications of some teachers of science and mathematics included in Table 1 of Appendix II in the column headed 'Others'. Designation as a teacher of a subject is no guarantee of adequate knowledge of the subject to be taught. Forty-six such cases were noted, three in chemistry, five in botany, nineteen in mathematics, eleven in physics and eight in biology. Many of those concerned teach in the middle or lower school, but a disturbing proportion teach in the higher forms and some are even responsible for organising the work in the subject throughout the school. Mathematics teachers include sixteen who have obtained no qualification in the subject beyond that of the Ordinary level of the G.C.E. In one case a two-year trained teacher is the organiser of the subject. Other qualifications of mathematics teachers include that of Bachelor of Music, pass degrees in Welsh and Latin and honours degrees in biology, botany, education and geography. The 'qualifications' of physics staff range from 'nil, untrained 'to honours degrees in geology, history and education. Chemistry is taught in three schools by graduates in mining, English and mathematics. Five graduates holding university subsidiary qualifications (first year post-Advanced level) in botany are responsible for the organisation of the work of that subject throughout the school. Biology is taught by six teachers who appear to possess no qualification in that or in any related subjects.

The number of graduates in these subjects who have followed a course of professional training is encouraging. Nearly 80 per cent of all teachers of science and mathematics have followed such a course, but of the younger graduates the proportion who have trained is lower than that for the group of older graduates. It is serious that the schools are now finding it necessary to appoint graduates in science and mathematics who have not followed a course of professional training.

Fig. 7.1

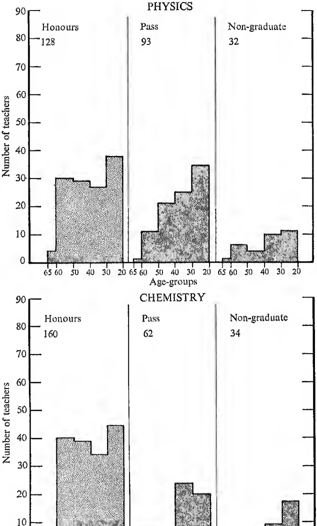
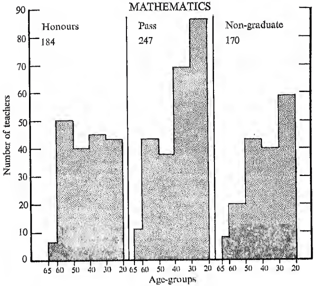
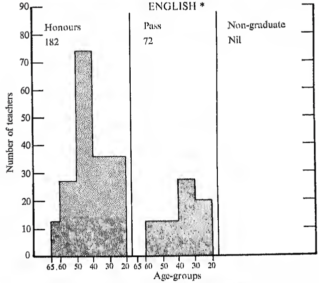

PHYSICS
Honours
128
Pass
93
Non-graduate
32
Number of teachers
90
80
70
60
50
40
30
20
10
0
65 60 50 40 30 20
65 60 50 40 30 20
65 60 50 40 30 20
Age-groups
CHEMISTRY
Honours
160
Pass
62
Non-graduate
34
Number of teachers
90
80
70
60
50
40
30
20
10
0
65 60 50 40 30 20
65 60 50 40 30 20
65 60 50 40 30 20
Age-groups

Fig. 7.1. (contd.)





* This histogram gives the distribution of degrees within a representative sample and shows the relative proportion of the various groups.

7.3 Staffing in Secondary Modern Schools

Our questionnaire to 223 secondary modern schools in Wales produced 200 replies. Of these, 159 schools had graduate heads, 43 in science and 116 in arts. This proportion of arts graduates is slightly higher than in the grammar and comprehensive schools. Twenty-one science graduates and eighty of the arts graduates had honours degrees.

Appendix III summarises the qualifications of the teachers of mathematics, physics, and science subjects other than physics.

These returns show a state of affairs just as disturbing as that revealed in the schools providing G.C.E. Ordinary and Advanced level courses considered above. About 80 per cent of the secondary modern schools in Wales have no teachers in mathematics, and about 87 per cent no teachers in physics, who are specially qualified for the work, either by the possession of a degree or by having completed a supplementary one year course. Of the 682 members of staff who teach mathematics and science, 377 (55 per cent) cannot be regarded as adequately qualified.

This dismal picture is alleviated to some extent by reports from some schools where individual teachers have developed an interest in science and mathematics and have become stimulating and enterprising teachers of these subjects in spite of their lack of formal qualifications. There can be no doubt, however, that this survey of staffing in secondary modern schools reveals a disturbing lack of qualified teachers in science and mathematics. We are of the opinion that the most energetic steps need to be taken to remedy this situation. It is clear that the normal processes of recruitment now operating will not substantially change this situation. Indeed, the number of teachers over 50 years of age contains a higher proportion of graduates than is found among the younger age groups.

Apart, too, from questions of qualification it is very doubtful if the total number of teachers of science and mathematics is adequate. Although one-half of the pupils attend secondary modern schools,these schools employ only about one-third of the number of teachers teaching these subjects in grammar schools. Even allowing for the heavy demands of sixth form teaching in the grammar schools it is clear that the modern schools are now able to cope with the situation only by teaching science to large classes for a relatively short time each week. We regard it as a matter of urgency that steps should be taken to provide these schools, in which the majority of our children are taught, with the staff necessary to give them the kind of education in science and mathematics which is appropriate to this age of rapid scientific and technological advance. The introduction of the proposed Certificate of Secondary Education will present a challenge to the schools of Wales which they are not sufficiently well prepared to meet in mathematics and science.

7.4 Laboratory Assistance

7.4.1 *Nature of Staff Required*

The need for the employment of trained laboratory assistants in secondary schools does not seem to be generally appreciated. In the 154 schools providing 'grammar' type courses, with 1,147 teachers of science, there are only 78 laboratory assistants and 90 per cent of these are employed by the Swansea, Cardiff and Glamorgan Local Education Authorities. Nine authorities have none at all and the remainder employ between one and four. The position is even worse in the secondary modern schools where 448 teachers of science work with virtually no assistance. The excessive burden of work, of a semi-skilled nature, which falls on science teachers is to be deplored. They have to cope with a range of tasks which include the unpacking of crates of new equipment, the construction and repair of apparatus, the preparation of solutions and specimens, the setting out of apparatus for practical lessons, the keeping of records of stores, the ordering of new equipment, and the maintenance of visual aids for the general use of the school. This formidable burden can be shouldered by the teacher only if he draws heavily on time which should properly be reserved for actual teaching, marking, preparation of lessons, developing new techniques and keeping up to date in the face of rapid changes in science. The help of pupils has frequently to be sought for carrying out many of these routine tasks; further erosion into valuable time occurs and this is often taken from the time allocation for practical lessons. That highly-qualified professional men and women have to spend so much of their time on this work is highly wasteful of time and money. This situation is undoubtedly a strong deterrent to the recruitment of well-qualified science teachers; it contrasts strongly with the conditions under which a scientist is expected to work in industry, or in a technical college or university laboratory.

We wish to make the strongest possible recommendation that local education authorities should establish schemes for the employment and training of laboratory assistants. No single step could do more to improve immediately the quality of science education, particularly in the light of the staffing situation described earlier. It is clearly more than ever necessary to make the most efficient use of those qualified teachers that the schools have been able to recruit.

In certain laboratories, particularly physics laboratories, two grades of assistant are needed. Firstly, there is need of a skilled technician with some knowledge of elementary workshop operations, both mechanical and electrical, and able to work with glass, wood, metal and plastic materials. Such a person needs the facilities of a small workshop with some simple equipment, such as a small lathe and drill, and could help not only in the maintenance and repair of modern scientific teaching equipment, but also in the equally important task of constructing apparatus designed for specific purposes by the science teacher or by able pupils. It is likely that schools will make increasing use of techniques involving the use of tape recorders, cine and strip projectors, amplifiers, television, loud-speaker systems, photography, stage-lighting, language laboratories and other mechanical teaching aids, all of which require essential and constant *skilled* maintenance. The senior technician needs to be supported by a general laboratory assistant who, though as yet unskilled in the strict technical, electrical or mechanical sense, is nevertheless capable of working under supervision and able to put out apparatus for practical and demonstration lessons and return it to store, prepare specimens and solutions and construct some of the simpler forms of apparatus. The general laboratory assistant would usually be a junior who would be concurrently attending a course of training at a local technical college with the aim of obtaining the Certificates of the City and Guilds of London Institute for Science Laboratory Technicians. On successful completion of the period of training and qualification, he would have an opportunity of employment as a senior technician and of a worthwhile career. Such work is well within the capabilities of pupils leaving secondary modern schools. It is indeed unrealistic to expect a pupil with G.C.E. passes in science subjects to give up the prospect of sixth form work in order to seek employment as a junior laboratory assistant.

The scale of this provision needs to be extended far beyond even that now being made by the most progressive authorities. In heavily used physics and chemistry laboratories one assistant is necessary for each laboratory; this means that, allowing for day release, he is available for four days a week. But in other cases it may be possible to share an assistant between two laboratories. The larger grammar and comprehensive schools frequently have five or more laboratories and need to employ their own senior technician. In the smaller schools, particularly the smaller secondary modern schools which often have only one or two laboratories, a senior technician could be responsible for a group of schools, working from a central workshop which could be located in one of the schools or even in a college of further education. The college location would carry with it the advantage of providing the facilities at the place where the junior asistants would be trained.

7.4.2 *Training Schemes*

Work as a laboratory assistant should not be regarded as a 'blind alley' job without career prospects. Recognised salary scales exist within the universities, starting with junior technicians who are paid a wage appropriate to their age, and rising through a technician grade to senior technician; promotion to the higher grades depends on the attainment of qualifications and the possession of special aptitude. Local education authorities, through their associations, have also recommended salary scales for various grades of technicians in school and technical college laboratories.

It has been suggested to us that many education authorities who do not now employ laboratory assistants would do so if an adequate supply of trained or partially trained personnel were available. There can be little doubt that at the present time the most urgent task is to build up as quickly as possible a supply of trained laboratory assistants who can staff schools which would then be available to employ more juniors to follow the traditional part-time courses of training. We favour the suggestion made to us that full-time courses should be established in some technical colleges to provide the initial nucleus of trained technicians. Such courses, of two years' duration, could recruit pupils leaving modern schools, preferably at 16 years of age, who would have studied mathematics, science and handicrafts with other subjects to the standard of the new Certificate of Secondary Education. The course would lead to the Science Laboratory Technician's Certificate after two years. At the end of the course the students would be suitably trained for employment in many school and college laboratories and could, through further study on a part-time basis, take the Advanced Certificate two or three years later. They would then be in a position to seek promotion to the higher grades of laboratory technician in other institutions or laboratories for which salaries of £1,100 per annum or even more are paid.

7.5 Laboratories and Equipment

It is clearly necessary for a school to be provided with sufficient laboratories, each large enough for its purpose. The Ministry of Education Building

Bulletins recommend a laboratory of about 1,000 square feet for the normal secondary school class of 30 pupils. There are, however, far too many new schools with laboratories of this size, but which subsequently have to accommodate larger classes. Particular difficulties have occurred in some of the larger grammar schools where sixth form classes in science have been more than doubled during the last ten years. The accommodation difficulty could frequently be solved by the splitting of large classes for practical work, if the necessary specialist staff were available. It is also unfortunate that, even in new schools, laboratories frequently have to be used as general teaching spaces, because of shortage of classrooms.

Evidence from several sources, however, leads us to believe that much has been done in the grammar schools of Wales in recent years to improve the science accommodation. The provision of new laboratories in the older schools has usually been in advance of the provision of other specialist accommodation and the most serious deficiencies now remaining are in schools which await remodelling or replacement.

The position in the secondary modern schools is much less satisfactory. Although some of the newer schools have good laboratories, many are still converted former elementary schools with inadequate facilities for science teaching. Evidence suggests that there is generally in the secondary modern schools a deplorable lack of well-planned and well-equipped laboratories for science teaching.

Some of the evidence submitted to us was critical of the planning and furnishing of science laboratories; it was suggested that there is often a failure on the part of architects to consult the teachers who will use the laboratories. Even when consultation takes place, it is often at too late a stage to influence the position of essential services such as drainage, water, gas and electricity supplies which affect the layout of the laboratory benches. Laboratories are sometimes too long in relation to their width and often contain too many windows, depriving the user of much essential wall space for fixed apparatus, particularly in physics. Storage space is not always well-planned and provided with shelves and cupboards of the appropriate size and shape to take apparatus such as metre bridges, barometer tubes and the varied sizes of bottles to be found in chemistry laboratories.

Whilst there was evidence to suggest that the grammar schools and the newer modern schools were reasonably well-equipped, there were certain aspects of the equipping of school laboratories which call for comment.

The bulk-buying of scientific materials and apparatus may have some financial advantages, particularly in the case of standard equipment such as glassware and chemicals, but for more specialised items the supposed financial gain has to be balanced against the disadvantages often encountered, such as the failure to obtain the apparatus specifically required on academic grounds by the science teacher. The advantages of the so-called 'Hertfordshire Scheme' by which schools have freedom to buy their own equipment, might be considered by more authorities. The increased numbers in the sixth form have posed problems to schools in obtaining the necessary additional apparatus which cannot be bought out of the usual annual grant for replacement of consumable material. There has generally been too little readiness on the part of schools to dispense with some traditional apparatus in favour of modern equipment which is often time saving, such as the modern rapid weighing chemical balance. There is, too, comparatively little apparatus available in the schools to provide the necessary experimental background for much of the new work, particularly in atomic structure, which forms part of theory syllabuses. The provision of such modern apparatus is an expensive item, but the high cost is not unrelated to the small demand. The manufacturers of scientific apparatus have shown commendable initiative in making much of this newer apparatus available to the schools, but a reduction in cost must await a considerable increase in its purchase by the schools. For very expensive apparatus local education authorities might consider it desirable to have a central source, either on loan to schools in turn or available for use by them in a central establishment. The initiative of one English authority, which has made a planetarium available in this way, is a commendably enterprising effort which shows that the difficulties of collaboration can be overcome.

It would be an advantage if means could be provided for teachers to see examples of good apparatus made in schools and colleges by other teachers and skilled technicians. The already excellent service to schools provided by the Schools Museum Service of the National Museum of Wales could with advantage be expanded to include such enterprises, particularly in the physical sciences. The larger authorities might indeed be able to make their own central provision consisting of a workshop with one or two assistants to demonstrate how simple equipment can be made and applied,

7.6 Summary

The present shortage of highly, or even barely adequately, qualified teachers in mathematics and science, together with the progressive decline in the standard of recruitment of teachers of science and mathematics, is the most serious problem affecting the teaching of these subjects in the schools of Wales.

This problem is not confined to Wales; it is, in fact, of world-wide extent. As far as Wales is concerned, at least we consider that the seriousness of the situation has not been adequately realised. It is becoming difficult, and may soon become impossible, to maintain a standard of teaching in mathematics and science even at its former level. Unless this trend is halted soon, the deterioration in the situation will certainly jeopardise any programme of expansion for universities and other institutions of higher education in mathematics and science.

We regard it as a matter of the greatest urgency that all steps should be taken by the Government to provide teachers qualified to give the kind of education in science and mathematics which is appropriate to this age of rapid scientific and technological advance.

A practice of permanently filling important teaching vacancies in secondary schools by applicants inadequately qualified in mathematics and science is to be deplored.

The amount of general laboratory assistance in the secondary schools of Wales is disturbingly small. We wish to make a strong recommendation that local education authorities should establish schemes for the employment and training of laboratory assistants and technicians, as a vital step towards improving the standard of science education.

Whilst much has been done in recent years to improve the science accommodation in the grammar schools of Wales, many secondary modern schools are still without adequately equipped and serviced laboratories. Also, when there are well-equipped laboratories, overcrowding in schools, due to unforeseen increase in numbers of pupils, sometimes prevents the proper use of those laboratories.

In the planning and furnishing of laboratories, there should always be consultation, particularly at the early stages, between the architect and the teachers who will use the laboratories.

Authorities should consider schemes which would allow schools freedom to buy their own science equipment, within annual cost limits. We consider that any advantages thought to accrue from the bulk-buying of scientific apparatus and equipment do not outweigh the disadvantages of preventing the science teacher from obtaining the specific apparatus he prefers.

Chapter VIII

SCHOOL LEAVERS

8.1 The Numbers

Much of the information submitted to us, particularly from industry, was concerned with the after-careers of school leavers and the relationship of the pupils' studies in school, especially of science, mathematics and English, to the kind of employment or further education subsequently followed. Views were expressed, often conflicting, on the adequacy or otherwise of the range of opportunity provided by Welsh industry and further education to meet the needs of school leavers, who show a considerable range of ability, achievement and age. We also obtained statistical information from the Ministry of Labour concerning the employment of juveniles and this is set out in Table 1 of Appendix IV. Information was also obtained from the statistical returns of the Ministry of Education and from the examination statistics of the Welsh Joint Education Committee. In addition, we obtained information direct from the grammar schools of Wales for the school year 1961–62 concerning the number of pupils leaving with minimum university entrance qualifications, their destination in the subsequent session, and the number of pupils pursuing sixth form courses at the second and third-year in the 1962–63 session. Statistics based on this information are set out in summary form in Tables 2, 3 and 4 of Appendix IV.

The numbers of pupils in the secondary schools of Wales since 1958 are given in Table 5 of Appendix IV. The rapid increase up to 1961 was a consequence of the high birth rate of the 1946–47 years, but the apparently static position in subsequent years is due to the fall in the birth rate being offset by the increased tendency to remain in school beyond the statutory school leaving age (Table 5). This position of stability is brought out in Table 5(b) which shows that the number of school leavers in the next decade is likely to remain constant at about 35,000 each year.

Of these about 9,000 (26 per cent) will have had a grammar school education and about 3,000 will have followed similar courses in other schools. These figures may, of course, show substantial changes in distribution if there are extensive changes in the pattern of secondary school organisation. The introduction of the Certificate of Secondary Education in 1965 is likely to influence the number of candidates for G.C.E. examinations.

8.2 G.C.E. Candidates

The extent to which school leavers are fitted for employment or further education depends largely upon their level of attainment on leaving school. The number of pupils entering and passing the Ordinary and Advanced level examinations of the Welsh Joint Education Committee is shown in Table 6 of Appendix IV. The great majority of these candidates are pupils from schools in Wales, but the table also includes mature students who have left school. There are, on the other hand, some schools in Wales which enter their pupils for the examinations of other Examining Bodies.

It can be seen that the total entry for the Ordinary level examinations has increased by 43 per cent in five years, but the number who sit for four subjects or more has increased by only 25 per cent. The number entering for one, two or three subjects has increased from 4,491 to 8,762, or by 82 per cent over the same period. It is clear that many pupils are entered for the Ordinary level examinations who cannot achieve a significant performance in terms of a group of subjects acceptable as an entry qualification to further education courses or even to a prospective employer. The introduction of the Certificate of Secondary Education should provide a much more suitable examination for many pupils of this kind.

The total number of candidates at the G.C.E. Advanced level has increased by 46 per cent over the same period, with the ratio of boys to girls remaining almost constant. About 2,000 pupils having four or more subjects at Ordinary level do not proceed to Advanced level in any given year, although many of these by part-time study while in employment continue their education in courses leading to the various National Certificates. Not all pupils, even when they have the necessary ability, wish to enter the Advanced level course. The increasing trend to stay at school after 16 years of age, coupled with the practice of some employers, particularly in the science-based industries, to recruit at 18 instead of 16, makes necessary the provision of alternative courses, such as the Ordinary National Diplomas in Engineering, Business Studies and Sciences in colleges of further education, to provide for the needs of such pupils.

8.3 Qualifications

While the total entry for examinations at the Advanced level has been increasing rapidly, there has also been a significant change in the subjects studied, in that the number taking science has increased considerably, especially among the boys.

The following table shows the change between 1956 and 1961.

Table 8.1 *Advanced Level Entry to Arts and Science*

<table>
<tr><th rowspan="2">Year</th><th colspan="2">Boys</th><th colspan="2">Girls</th><th colspan="2">Total</th></tr>
<tr><th>Arts</th><th>Science</th><th>Arts</th><th>Science</th><th>Arts</th><th>Science</th></tr>
<tr><td>1956</td><td>502</td><td>1,391</td><td>764</td><td>511</td><td>1,266</td><td>1,902</td></tr>
<tr><td>1961</td><td>632</td><td>2,213</td><td>1,062</td><td>797</td><td>1,694</td><td>3,010</td></tr>
<tr><td colspan="7">The ratios of pupils taking arts subjects to those taking science subjects, as obtained from the above figures are:</td></tr>
<tr><td>1956</td><td colspan="2">1 to 2·62</td><td colspan="2">1 to 0·67</td><td colspan="2">1 to 1·53</td></tr>
<tr><td>1961</td><td colspan="2">1 to 3·50</td><td colspan="2">1 to 0·75</td><td colspan="2">1 to 1·85</td></tr>
</table>

The marked difference in the ratios for the boys and girls is worth considering in more detail. The performance of boys and girls from mixed and single-sex schools in achieving minimum university entrance requirements can be compared from Table 3 of Appendix IV. The following table gives the ratio of science to arts pupils for boys and girls in each type of school. The first row gives those who qualified to enter a university; the second row gives those who actually entered.

Table 8.2 *Comparison of the Numbers of those taking Science to those taking Arts for Boys and Girls at University Entry*

	Boys in Boys' Schools	Boys in Mixed Schools	Girls in Girls' Schools	Girls in Mixed Schools
With Minimum Requirements	1·34 to 1	2·24 to 1	0·51 to 1	0·41 to 1
Entering the University	1·42 to 1	2·92 to 1	0·63 to 1	0·57 to 1

The proportion of girls taking science in girls' schools to those taking arts (0·51 to 1) is higher than that in mixed schools (0·41 to 1). This is contrary to the widely held belief that the low proportion of girls taking science is due to the lack of opportunity in girls' schools. In mixed schools, where the science facilities are presumably the same for boys as for girls, the proportion of boys taking science to those taking arts is five times greater than is the case for girls.

It is clear also that the proportion of boys taking arts in boys' schools to those taking science (1 to 1·34) is higher than that in mixed schools (1 to 2·24). There would appear to be a strong tradition in mixed schools that science subjects are for boys and arts subjects for girls. In view of the figures for single-sex schools, the validity of this assumption is doubtful, to say the least.

A comparison of the proportions in the lower row with those in the upper row shows that they are greater for those who actually enter the university than for those who obtain the minimum entrance qualifications. This fairly substantial increase (about 25 per cent for girls but rather less for boys) may be due to the fact that a higher proportion of the able pupils are opting for science; on the other hand, it may be due to the fact that it may be possible to secure a university place more easily in faculties of science, applied science and technology than in arts faculties.

It is also possible to compare the Welsh Joint Education Committee entry figures with the examination results of candidates passing in two or more Advanced level subjects.

The ratio of the number of boys taking science to boys taking arts sitting Advanced level examination is 3·5 to 1 but the ratio of those who pass in science to those who pass in arts is 2·1 to 1. The corresponding figures for girls are 0·75 to 1 and 0·45 to 1 respectively. Thus, as far as numbers are concerned for both boys and girls, arts candidates are more successful than science candidates in achieving two Advanced level passes.

8.4 Destinations

The immediate destinations of school leavers in Wales are summarised in the following table taken from the statistical returns of the Ministry of Education:

Table 8.3 *Destinations of All Leavers*

Year	1958	1959	1960	1961	1964 – 1970 (Estimated)	
University	1,448	1,434	1,642	1,768	2,200	3,000
Teacher Training Colleges	1,011	1,103	1,249	1,374	2,000	2,500
Technical Colleges and Establishments of Further Education	1,732	2,380	2,538	3,070	4,500	8,000
Employment	27,957	29,500	29,778	29,713	28,800	20,500
Total	32,148	34,417	35,207	35,925	37,500	34,000

On the basis of national policy up to 1963*, the number of entrants to the universities and training colleges was expected to rise by nearly 2·5 times between 1958 and 1970. The number entering technical colleges was expected to increase six times, but the increase between 1958 and 1962 was already nearly three times, although official statistics show that most of the increases are in fact due to an increase in the numbers within the 15–17 age range.

An attempt has been made to account for the pupils who left the sixth form in 1960–61 and 1961–62 and relevant figures are set out in Table 8.4. Because of changes in the method of presenting statistics from year to year and the lack of separate information for Wales in some instances, it was difficult to obtain the specific information which we required. This was one of the reasons why we sent out our own questionnaire. However, we give in Table 8·4 the figures in the various categories in 1960–1961 obtained or estimated from statistics published. For 1961–1962 we give the corresponding figures from statistics published, together with the results of our own questionnaire. The results of the questionnaire gave information from 155 out of 159 grammar schools and schools with grammar streams in Wales.

Table 8·4 shows a marked increase in the number of pupils (from 151 to 723) who did not proceed to higher education in the two years under consideration. Since the employment situation did not change substantially in this period, this is more likely to be due to shortage of places in higher education. Under these circumstances it is disappointing to record, as at the time of the issue of the Council's report on *Technical Education in Wales*, that some places in the technical colleges of Wales offering advanced full-time and sandwich courses still remain unfilled.

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* These estimates will have to be modified if the recommendations of the report of the Committee on Higher Education are implemented.

Table 8.4 *Destination of Sixth Form Leavers with Two or More Advanced Level Passes*

	1960–61	1961–62	
Year	From Statistics Published	From Statistics Published	From Grammar School Questionnaire
Number of Students with two or more Advanced Level Passes	2,438	2.973	3,006
Entered University	1,768	*1,650	1,595
Teacher Training Colleges (Wales and England)	*349	*350	369
Technical Colleges	*170	*200	223
Returned to School or entered Employment (calculated from lines 1–4 above)	151	723	819 (834 from the returns)
*Estimated figures			

There are many pupils who hold good Ordinary level certificates but who either have failed completely at Advanced level or have passed in one Advanced subject. These could profitably proceed to some form of higher education. The following table gives the numbers for the years 1960–61 and 1961–62.

Table 8.5 *Advanced Level Passes*

	1960–61	1961–62
Passed one Advanced Level Subject	1,265	1,269
Sat Advanced Level but failed	1,001	1,282

8.5 Higher Education

About 300 of the pupils who passed in one Advanced level subject in 1960–61 proceeded to training colleges in England or Wales and a number returned to school to attempt to improve their performance at the Advanced level examination in the hope of entering a university in a subsequent year. This number could not be more than about 250, however, because the total number of third year pupils in 1961–62 is 770, as can be seen from Table 4 of Appendix IV, of whom 530 were returning with two or more Advanced level passes as shown in Table 2.

We cannot therefore escape the conclusion that there are substantial numbers of pupils in the sixth forms of Welsh secondary schools or pursuing G.C.E. Advanced level courses in colleges of further education who are being lost to higher education. These find themselves at 18 years of age seeking employment, having missed the opportunities afforded to the 16 year old school leaver to enter apprenticeships of various kinds. This number is probably not less than about 1,700 a year, of whom it is likely, from conclusions drawn in an earlier section, that the majority are science students.

We are of the opinion that it is at least possible that some science students who now fail to achieve anything worth while at the Advanced level examinations might follow with greater profit full-time and sandwich courses in engineering and applied science subjects leading to the Ordinary National Diploma. These courses, taken in a technical college, place special emphasis on practical applications. In the same way many of the arts students might profit from similar courses in business studies. Another possibility would be for those who have passed in only one Advanced level subject after two years in the sixth form to enter appropriate courses in institutions of higher education instead of returning to school to attempt to improve their performance. It is unfortunate that vacant places still exist in full-time courses in technical colleges for both science and arts students at a time when the country is short of engineers, scientists, accountants, etc. at all levels.

In another section we refer to the serious shortage of teachers of science and mathematics in the secondary modern schools of Wales. It seems to us that many young people among the sixth formers who now fail to obtain university entry, given the opportunity, might make good teachers of science; this has particular relevance to present needs of secondary modern schools where a high proportion of pupils are being taught in science and mathematics by teachers with no qualifications at all in these subjects. Only two per cent of school leavers with two Advanced level passes in science subjects enter training colleges—a total of 60 pupils a year (Table 2 of Appendix IV).

8.6 Apprentices

Industries vary greatly in the relative numbers of recruits which they require at each level. Some of the heavy industries of South Wales require that a much higher proportion of their total personnel should be technicians and craftsmen, while those industries operating processes involving a high degree of scientific control demand much higher proportions in the highly skilled categories. It is generally recognised that in order to utilise the capacity of a scientist or a technologist for initiating progress, his technical support forms a 'pyramid'; he requires about five or so technicians, each of whom might require a similar number of craftsmen in support. At the base of the 'pyramid' are large numbers of operatives who vary from one industry to another both in quantity and in degree of skill.

Table 8.6 shows that some industries recruit much less than the proportion of boys under 18 necessary to fill their quota of adults. The proportion of the total labour force employed in mining and quarrying is 10·4 per cent of adults and 11·5 per cent of juveniles, suggesting that if the industry is not expanding or contracting greatly it is recruiting about the right number of young men. This is roughly true of some other industries listed, but others, for instance, agriculture, have a much higher proportion of young workers. Since the industry is not an expanding one, agriculture is clearly employing nearly three times as many juveniles as it can ultimately absorb. The expanding industries, for example chemical and allied industries, employ only a third of the proportion of juveniles that they will ultimately need.

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Table 8.6 *Employment Distribution* (1963)

Industry	Total Number of Insured Employees	% of Total in all Industries	Males under 18	% of Total in all Industries
Mining and Quarrying	102,610	10·4	4,630	11·5
Gas, Electricity and Water	21,460	2·2	540	1·4
Transport	76,030	7·7	1,600	4·0
Agriculture, Forestry and Fishing	22,640	2·3	2,460	6·1
Chemical and Allied Industries	23,740	2·4	380	0·9
Metal Manufacture	91,540	9·3	2,590	6·5
Vehicle Manufacture	17,540	1·8	500	1·3
Shipbuilding, Engineering and Metal Goods	77,420	7·9	3,450	8·6
Textiles	17,220	1·7	420	1·1
Clothing	14,600	1·5	410	1·0
Food, Drink and Tobacco	22,270	2·3	1,410	3·5
Other Manufacturing Industries	43,800	4·5	2,500	6·3
Construction	79,750	8·1	5,600	14·0
Distributive Trades	111,150	11·3	7,690	19·2
Professional Services	114,720	11·7	890	2·3
Miscellaneous Services	77,800	7·9	3,880	9·7
Unclassified	150	—	—	—
Public Administration	68,560	7·0	1,050	2·6
Total	983,000	100·0	40,000	100·0

8.7 Summary

Whilst the total entry for the Ordinary level examinations has increased by 43 per cent in five years, the number who sat for four subjects or more has increased by only 25 per cent. Many pupils are entered who cannot achieve a significant result in terms of a group of subjects. The Certificate of Secondary Education examination should be a more suitable one for these pupils. Pupils in the arts sixth form are more successful than those in the science sixth in achieving two Advanced level passes.

There are about 1,700 students a year, either in the sixth forms of schools in Wales or following General Certificate of Education Advanced level courses in colleges of further education, who find themselves at 18 years of age seeking employment.

Many of these pupils would have been better advised to enter full-time or sandwich courses in engineering, applied science or business studies in a technical college instead of pursuing G.C.E. Advanced level courses.

Chapter IX

TRAINING COLLEGES

9.1 Nature of the Courses

During the past four years important and necessary changes have taken place in the training colleges. In 1960 came the extension of the course of training from two to three years and immediately following this, the colleges were faced with the necessity of preparing for a rapid expansion programme. By 1970 it is estimated that the total number of students will be more than twice the number in colleges in 1960. In order to obtain information on the numbers of students and the general staffing position, we sent a questionnnaire to all the general training colleges in Wales.

In Wales there are eight general training colleges where students are prepared for the Teacher's Certificate of the University of Wales School of Education. The regulations governing the award of the Certificate are laid down by the School of Education. The scheme of study consists of a professional course together with two Main subjects, or one Main subject with two Subsidiary courses; one Main course may be pursued at Advanced Main level. In addition to practical teaching in the schools, the professional course includes Principles of Education, English, and where appropriate, Welsh, Mathematics, and Physical and Health Education. A course in Bilingual Method is provided for suitably qualified students who seek a Certificate of Proficiency in Bilingual Teaching. This combination of professional and academic study running concurrently is a distinctive feature of training colleges. The relevance of the vocational aspect of the training makes more significant the more purely academic side of the student's further education. Whilst recognising the importance of furthering the student's personal education and the value of learning for its own sake, the character and organisation of the professional training must be related to the needs of the maintained schools. Population trends over the years 1961–1970 show a substantial and sustained increase in the numbers of pupils in the primary schools. It is the policy of the Ministry of Education that the pattern of training in the general colleges taken as a whole should be such that 80 to 85 per cent of the students (compared with 63 per cent in 1960) will be needed to staff the primary schools and about 15 per cent for teaching in the secondary schools, in particular to teach those subjects for which the universities do not cater (e.g. physical education, handicrafts, etc.) or do not cater sufficiently (mathematics, science).

It is the almost exclusive responsibility of the general training colleges to train teachers for the primary schools and to some extent for the 'shortage subjects' in secondary schools. This demand for teachers for secondary schools is more than likely to increase over the next decade. The total number of places in the eight general colleges of Wales was expected to be 3,000 by 1966 with an estimated further expansion to about 4,500 by 1970; but this figure of 3,000 has already been exceeded.

The training colleges of Wales have, over the past years, made a significant contribution to higher education. Of the total leavers during the year 1961 from schools in Wales 3·8 per cent entered training colleges, which is about double the percentage from England and Wales taken as a whole.

9.2 Qualifications of Students on Entry

Most of the students who enter training colleges come straight from the grammar schools and the majority will have spent at least one year or more in the sixth form. Applicants who can offer only the bare minimum requirement of five subjects at the Ordinary Level of the G.C.E. stand little chance of acceptance. For the year 1961, two per cent of the women students and nine per cent of the men entered college on the minimum requirements: of these some would be mature students who could offer additional qualifications not covered by G.C.E. examinations. For the same year 43 per cent of the women and 41 per cent of the men obtained passes in one or more Advanced level subjects: passes in arts subjects far outnumber those in science and mathematics. Students admitted to the colleges today often suffer from an inadequate grounding in the sciences and mathematics. In the experience of the colleges, it is also far too common to find applicants who have no qualifications in, for example, geography or history. This reinforces the plea for balance, recognising that imbalance is not necessarily a weakness found only on the mathematics and science side. Applicants to training colleges whose education lacks this essential balance and coherence, for example, a candidate who offers only a chance selection of Ordinary Level subjects, are ill-equipped to profit from a three year course of training for the teaching profession.

9.3 Mathematics

The training colleges have to give thought to the whole question of curriculum and method in the primary schools. Under the regulations governing the award of the Teacher's Certificate of the University of Wales, a course in mathematics is now included as a compulsory part of the professional course. This, it is hoped, will help to meet the criticism, increasingly made in recent years, that many young teachers are unable to teach arithmetic and it will go some way to ensure that the new generation of teachers passing through the colleges at present will be well-equipped not only to teach arithmetic but to extend their teaching to the wider field of mathematics.

For the years 1960 and 1961, 66 per cent of the men and 40 per cent of the women entrants had obtained an Ordinary level G.C.E. pass in mathematics, a further 13 per cent of the men and 25 per cent of the women obtained a pass in the Special Examination in Arithmetic. Students who have successfully followed mathematics up to the Ordinary level of the G.C.E. have, in general, an adequate background knowledge and possess reasonable technical skill, though understanding of mathematical processes, as distinct from automatic use of computational skills, is often lacking. A number of students enter college with meagre attainment and with no taste for mathematics and many have developed a dislike of the subject and a fear of their inability to cope with it. One-third of the women and one-fifth of the men who enter the training colleges in Wales have no G.C.E. qualifications in mathematics. This is a most serious situation. The effectiveness of the teaching of mathematics ultimately depends on the teacher who is well-qualified, enthusiastic and responsive to the needs of the children.

It is generally felt that the basic professional course develops in the students confidence in their ability to deal with mathematics and their interest in the principles under discussion is enhanced when it is realised that these possess practical significance for teaching.

It is to be deplored that many students, more especially women, drop mathematics before reaching the Ordinary level of the G.C.E. The Special Examination in Arithmetic (often taken as a 'soft option') with its emphasis on computation is an inadequate preparation for the professional course in mathematics. Evidence suggests that consideration needs to be given to a more appropriately devised syllabus with a less academic approach. It has been suggested that all entrants to training colleges should have passed in mathematics at the Ordinary level. Though this is a highly desirable requirement, it would be unrealistic to make this a compulsory condition for entry, as there is at present an insufficient number of applicants to the training colleges with Ordinary level qualifications in mathematics as part of a balanced group of subjects. Many of the applicants without Ordinary level mathematics will have passed only the Special Examination in Arithmetic. The fact that it is possible at present to be accepted for a training college without Ordinary level mathematics lessens the inducement to pursue mathematics to Ordinary level at school among those who wish to proceed to training colleges. Evidence we have received urges the discontinuance of the examination in Special Arithmetic. Whilst recognising the useful purpose which this examination has served, particularly from the standpoint of training college recruitment, many now question its usefulness, particularly since there are grounds for believing that the existence of this paper encourages concentration upon arithmetic to the neglect of wider aspects of mathematics.

Many pupils pursue general courses in the sixth forms as a preparation for entry to training colleges. We would urge that mathematics be included in such courses.

All colleges offer mathematics as an Advanced Main or Main course. In 1963, the year of the first leavers from the three year course, 82 pursued mathematics as an Advanced Main or Main course subject, but only a limited number of these will have been trained to be specialist teachers of mathematics in secondary schools. The number of places allocated to Wales for the training of such teachers is limited. As the present drastic shortage of mathematics teachers is likely to continue and increase over the decade, modern and grammar schools are looking to the training colleges for staff recruitment. Over the past years students who have specialised in mathematics find no difficulty in obtaining posts in secondary schools. We shall comment further on this in Chapter XIV.

9.3.1 *Supplementary Courses for In-service Teachers*

The supplementary course in mathematics for qualified teachers after a period of service in the schools (discontinued with the introduction in 1960 of the three year course of initial training) has been re-introduced at Trinity College, Carmarthen. The number of applicants for the 1963-64 session was encouraging and is an indication of the awareness of teachers of the need for further specialised training for teaching in both primary and secondary schools.

In view of the serious shortage of teachers with qualifications in mathematics, already discussed above, we would recommend that many more practising teachers should be encouraged to pursue this course. We note that there is only one college at which this course may be pursued, but we have no doubt that further facilitities could be made available when the demand is established. Non-residential courses, for example, would be suitable for married teachers.

9.4 Science

Table 9.1 *Science in the General Training Colleges. Advanced Main and Main Courses*

College	Subject	Type of Course
The Normal College, Bangor	Biology Physical Science Rural Science	Main Advanced Main and Main Main
St. Mary's College, Bangor	Biology	Main
Trinity College, Carmarthen	Biology Rural Science Physics	Main Advanced Main Main
The Monmouthshire Training College, Caerleon	Biology Horticulture Physical Science	Advanced Main and Main Main Main
The Glamorgan Training College, Barry	Biology Science	Main Main
The Training College, Swansea	Biology Physical Science	Main Main
Cartrefle Training College, Wrexham	Biology	Main
The City of Cardiff Training College	Biology	Main

Table 9.1 gives in outline the various science courses at the colleges in Wales. It will be noted that the physical sciences are not taken in every college. The numbers of passes in the various sciences are given in Appendix V. It will be seen that the numbers taking the physical sciences for the Teacher's Certificate are much less than those in any other subject. However, the proportion may well increase since more colleges have recently introduced courses in the physical sciences. Also, since the introduction of the three year course in 1960, students may take two Main courses. Only a small minority of women students take Main courses involving the physical sciences.

Rural science may be taken at two of the colleges. It is disappointing to find that the number of students choosing this subject is small at present, despite the facilities for the training of teachers for rural science and the important part the subject could play in the curriculum of the schools, especially in rural secondary schools.

Teachers of science in secondary modern schools are generally required to take classes both in the physical and in the biological sciences. Hence in the training colleges those students who are being trained specifically for taking science in secondary schools should take both physical science and the biological sciences (including geology) as main subjects. But the evidence received indicates that the number of students who follow both as Main course subjects is inadequate. Those electing for a Main course in biology or rural science are reluctant to take physical science as a second Main subject; whilst those taking physical science often take mathematics as their other subject. If the training colleges are to help to satisfy the needs of the secondary schools in Wales, it is at least necessary that the quota of 46 places of those to be trained specifically for secondary school teaching should follow two Main courses in science. This quota of 46 places is wholly inadequate to meet the needs of the schools and it is disturbing that up to the present all the places are not being filled. Much is being done to bring to the notice of prospective entrants the needs of the schools in the shortage subjects, but direction of students is undesirable, The training colleges are faced with difficulties not only in training students to become teachers of science in secondary schools but also to become teachers in primary schools where 80 to 85 per cent of them will eventually teach. Subsidiary courses are designed more especially to meet the needs of students who will eventually teach in primary schools. They need to have their knowledge of the subject extended, to know how to relate their knowledge to pupils' needs and to be able to teach the subject in an interesting manner. In formulating courses in junior school science, colleges are handicapped by the inadequate background knowledge possessed by many of the students on entry.

9.5 Staff

Table 9.2 *Science and Mathematics Staff*

Year	Total Number of Lecturers	Science/ Mathematics Lecturers
1956	147	18 (12·6%)
1957	155	21 (13·4%)
1958	160	21 (13·1%)
1959	166	26 (16·0%)
1960	199	31 (15·6%)
1961	213	37 (17·3%)
1962	279	41 (14·7%)
1963	320	50 (15·6%)
1966	380*	76 (20·0%)*

* Estimated figures.

It can be seen from Table 9·2 that the number of lecturers in mathematics and science has nearly trebled over the period 1956–63 and the percentage of mathematics and science staff to the total staff has increased from 12·6 per cent to 15·6 per cent. The last row in the table gives an estimate of the position in 1966.

Most colleges state that they have, eventually, been able to fill the vacancies that have arisen through resignations and additional staff requirements for the expansion programme. However, great difficulty is experienced in obtaining lecturers in mathematics and the sciences with suitable qualifications (Class I or II A honours degrees) coupled with training and teaching experience. The field of applicants is very limited. Less than one-third of the mathematics lecturers, and rather more than one-half of the science lecturers, have good honours or higher degrees. The majority of lecturers have had considerable teaching experience in schools, but the number and quality of the applicants over the last few years have not always been adequate.

Those who have not graduated in mathematics have graduated with honours or pass degrees in a science (e.g. physics, zoology, geography) which included mathematics at pass degree or a lower level. Although their main lecturing is done in this science subject, nevertheless they are called upon to take classes in mathematics for the Subsidiary and Professional Courses. This illustrates the difficulty of obtaining lecturers with good qualifications in mathematics to meet the needs of training colleges.

In the colleges where students may pursue courses through the medium of Welsh, the difficulty is further increased, as some lecturers will be required to have a sound knowledge of the Welsh language. It is very difficult to get suitably qualified women lecturers for the mixed or women's colleges as very few women apply. This shortage of women applies to some extent to all subjects, and it appears that the quality of women applicants is generally not as good as that of the men. Even where colleges have felt it desirable to appoint women, the posts have often been filled by men. Both the number and the quality of applicants in recent years for posts in arts subjects are on the whole better than for science.

9.6 Laboratory Assistance

The majority of the colleges have no trained technicians or laboratory assistants; only in one college is there a trained laboratory technician. Two colleges have assistants in the biological departments. Colleges have been unable to appoint laboratory assistants: repeated advertisements bring no applicants from trained people or school leavers wishing to be trained.

9.7 Summary

Entrants should be required to have passed in mathematics at the Ordinary level of the G.C.E., as part of a balanced group of subjects including science, as soon as the supply situation warrants.

Those students who are being trained specifically for teaching science in secondary schools should take both physical science and biological science as Main subjects.

The present quota of places available for students to be trained for teaching mathematics and science in secondary schools is wholly inadequate. The question of the proportion to be trained for secondary school teaching in certain subjects should be reviewed in the light of the present situation.

The lack of adequate laboratory technical assistance is serious.

Chapter X

THE TECHNICAL COLLEGES

10.1 Numbers of Students and Nature of Courses

In common with institutions of higher education, the technical colleges are concerned with the attainments in mathematics and science, as well as with the general balance of education, of the secondary school leavers. For the individual college student, specialisation in science diminishes the element of balance but the inclusion of general studies mitigates this disadvantage. The fairly general expansion of courses in such arts subjects as foreign languages is resulting in an improved range of courses.

As industry and commerce increase their demands for trained staff at all levels, so the content and balance of the courses must be examined and amended. This, in turn, leads to an increased and more varied demand for staff, mainly from universities, but an increasing proportion is recruited from the colleges themselves. From their foundation (in some cases as mechanics institutes) for the improved education of craftsmen, the technical colleges have developed into institutions within which a wide spectrum of courses from craft to honours graduate level is available. The history of this development, and indications of future progress have been dealt with fully in the Council's last report *Technical Education in Wales*, and the statistics given below serve to extend the data and confirm the forecasts.

Table 10.1 shows the numbers of students attending technical colleges in Wales from 1959, with estimates for 1964 and 1970, based on the 1961 Report of the National Advisory Council for the Training and Supply of Teachers.

Table 10.1 *Students attending Technical Colleges in Wales*

Year	1959	1960	1961	1962	1963	1964*	1970*
Full-time	4,365	4,699	5,659	5,477	6,703	8,000	11,000
Sandwich	426	525	591	707	911	1,100	2,200
Part-time day	23,592	23,601	26,186	26,228	27,845	28,500	32,500
Part-time evening	27,670	28,297	29,574	29,093	29,956	32,500	38,800
TOTAL	56,413	57,092	62,010	61,505	65,415	70,100	83,500
Released by industry	22,609	22,356	24,532	26,880	26,354	26,500	30,000

* Estimated figures.

The indications of rapid development of full-time and sandwich courses in recent years, as well as the general increase in the numbers of students of all kinds, are encouraging, but the actual contribution to higher education at various levels can be determined more accurately from Table 10.2. This shows, in the first five rows, for example, that there has been a significant increase in the number taking post Advanced level courses. In spite of this trend, however, statistics of the Ministry of Education show that the total number of students attending these courses in Wales is a smaller proportion of the appropriate age group than is the case in England. This is probably because of the lack of those industries in Wales which require large numbers of highly skilled and trained employees. Another factor is that, for example, in 1961 only 19 per cent of the boys who entered Welsh industry did so as apprentices, compared with an average for England of 35 per cent and 45 per cent for the best English area.

Table 10.2 *Students Following Courses leading to a Qualification*

Year	1960		1961		1962		1963	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Degree	90	15	127	20	113	30	114	41
Dip. Tech.	99	2	122	2	146	2	207	0
H.N.D.	233	2	266	2	333	3	402	10
H.N.C.	1,835	21	1,841	29	2,095	33	2,226	32
Other Advanced	908	58	1,328	67	1,650	108	1,851	115
O.N.D.	115	0	102	0	134	46	200	129
O.N.C.	6,809	234	7,205	264	7,318	288	5,409	246
City and Guilds	11,428	808	13,122	1,079	15,139	1,059	17,575	1,114
Other Non-Advanced	3,284	1,044	2,922	962	2,869	1,261	2,675	1,188
G.C.E. 'O'	1,765	898	2,041	1,040	2,787	1,520	3,481	2,406
G.C.E. 'A'	386	140	576	168	601	231	734	258
TOTAL	26,952	3,222	29,652	3,633	33,185	4,581	34,874	5,539
Full Time	1,401	1,095	1,783	1,261	2,046	1,794	2,497	2,166
Sandwich	521	4	587	4	690	5	891	20
P.T. Day	16,381	649	17,291	821	20,283	901	21,958	1,069
P.T. Evening	8,649	1,474	9,361	1,547	10,166	1,881	9,530	2,284
TOTAL	26,952	3,222	29,652	3,633	33,185	4,581	34,874	5,539

10.2 Entry Requirements

The requirements for entry at the various levels range from the completion of four years of secondary education to a combination of three subjects at Advanced level and English at Ordinary level. Those students who satisfy the entry requirements, at Ordinary or Advanced level, find the transition a relatively smooth process so far as the college courses are concerned. Some students, however, find serious difficulty in adapting themselves to such courses since the physical and mental demands of their new employment, as well as the radical change from the school atmosphere, require a capacity for adjustment which many do not posesss.

Where the entry requirements are only vaguely specified, as in most of the craft and operative courses, the position is rather less satisfactory, in that the level of attainment in mathematics, science and English is often very poor.

We have received evidence that the proportion of such students has been as high as two-thirds of the entry from secondary modern schools. Pupils from any kind of secondary school who have taken general science throughout the school, and who may also only take arithmetic instead of a broader course in mathematics, are generally not well-equipped for entry to National Certificate courses. Pupils who show promise in school in mathematics and science may without any external examination requirement enter on a general course in a technical college. If this is completed at a satisfactory level a student may then embark on a National Certificate course.

10.3 Relative Numbers of Technologists, Technicians and Craftsmen in Industry

We have previously pointed out that the full potentiality of a technologist or scientist can only be realised if he is supported by appropriate numbers of technicians and craftsmen. The proportions for the three categories required vary with the type of industry and have been variously estimated as lying between 1 : 3 : 15 and 1 : 10 : 150 for industry as a whole, but for our present purposes we shall take 1 : 5 : 25.

Using the figures of Table 10.2 we estimate that the actual annual output of the technical colleges of Wales is about 150 technologists, 1,000 technicians and 1,500 qualified craftsmen. The number of 'craftsmen' produced may be as high as 5,000 per year, because it is unfortunately true that an apprentice can complete his indentures without passing any test of skill or ability. Even if we take this figure of 5,000 as valid, this is the proper 'support' for only about 200 technologists per year.

As we have seen above, there are about 150 technologists produced by the technical colleges, but in addition, as shown in Chapter XI, about 580 technologists and scientists (not counting those who become teachers) are produced annually by the University of Wales. Thus there are about 730 technologists being produced annually in Wales whereas the total number of craftsmen (even optimistically estimated) can support only about 200.

Clearly, the majority of technologists (530 out of 730) must be seeking employment in industry outside Wales. It is perhaps only reasonable that this should be so under existing social and industrial conditions for, if all these technologists were to remain in industry in Wales engaged in production (rather than in, say, a research establishment), they would require something like 18,000 craftsmen annually. Unless the whole structure of Welsh society were to become completely unbalanced it would follow that this number could only be assimilated within a total population possibly twice or three times greater than the present population. Considerations such as these raise sociological questions which lie outside our terms of reference.

10.4 Preparatory Courses for Technologists

The production of technologists from the technical colleges is in part from students entering with Advanced level qualifications, but to a much greater extent from students who enter with Ordinary level or less, and proceed by way of the Ordinary National Certificate to advanced courses. The number of Ordinary National Certificates in technological subjects has averaged about 900 a year in recent years, and is expected to rise to about 1,500 a year by

1970. This estimate does not allow for the reduction in wastage which would follow the introduction of block release or sandwich courses, and which might easily raise this figure to 2,500 in 1970. These figures draw attention to the difference of opinion as to the best time of entry into a technical college for the student wishing to make a career in industry. Some employers prefer to engage students at 16, with at least four Ordinary level subjects, and to require them to follow a two year part-time course to the Ordinary National Certificate for diagnostic purposes. Others prefer entrants who have taken Advanced level at school and who will proceed directly to advanced courses. We have previously pointed out that in the past it has proved difficult to interest grammar school pupils of 16 or so in work in industry involving part-time education. However, we would like to record that we have been greatly impressed by the social and educational background conducive to the full development of the young entrant direct from school which can be, and is, provided by the best type of modern, science-based, industrial concern.

10.5 General Studies

Specialisation, leading to an illiberal attitude to studies, is a danger common to all forms of higher education in this country, but the danger may well be greatest for students pursuing part-time courses in technical colleges. In 1955, when the National Institute of Adult Education published its survey* of the relationship of vocational and non-vocational further education and training, there was abundant evidence that vocational, especially technical, education had been too narrowly conceived. Some part-time students are so weighed down in their first years by the combination of earning and learning that their opportunities for relaxation and cultural activities are severely restricted; and there are some cases where the concentration on the purely technical work and the resultant intellectual stagnation have caused ill-health.

Following the special provision made for the incorporation of general studies as an integral part of courses leading to the Diploma in Technology, there has developed a greater awareness that a narrow technical course of instruction is not enough on its own to produce the 'whole man capable of living the good life amid the scientific complexities of modern life'. General studies are being offered increasingly to full-time sandwich course students, and attempts are being made to extend these to all part-time courses.

We recommend that in all technical college courses—full-time, sandwich and part-time—general studies, liberally conceived, should be amply provided for and that an effective proportion of students' time should be allotted to such studies. These studies, if they are to be of value, must be included in the curriculum for their own sake; to make them dependent upon the purely technical courses is to deny them the very qualities which make them liberal and humane.

Some of the elements in these studies, for example, art, music, drama, can be varied to suit the special needs of groups of students. There are others, however, which must be offered to all students. Since one of the aims of general studies is to develop clear expression of ideas, a prominent place must be given to the mother tongue both as a means of communication and as the vehicle of a literature conveying the thoughts and feelings of men throughout the centuries.

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* *Liberal Education in a Technical Age*. London, 1955.

Language on its own is a useless tool unless the student has thoughts and ideas which he wishes to express. We understand that too many students in technical colleges have so little knowledge, experience or even interest relating to matters outside the utilitarian aspects of their technical courses, that to encourage any kind of discussion among them proves difficult, and almost impossible, except on the most elementary level. The lack of curiosity and the passive attitude towards the acquisition of knowledge is a sad commentary on students' earlier education. There is a strong feeling that lecturers in technical colleges are attempting to accomplish something at too late a stage. It follows from this that another element in the general studies of students must be courses aimed at giving them some grasp of the manifold activities of men outside their technical studies. The social studies, particularly history, would introduce them to such activities, both in the past and in the present, give them a wider and more balanced view of life, and help them to see their technical studies in a better light.

Such courses in general studies for part-time students should include formal instruction and experimental work in oral and written communication. The main approach should be through a particular interest and involvement, and proceed from the main subject of study.

Student clubs promote general education, but on their own they are not enough; they must be supported by planned courses in general studies. However, with the increase in full-time and sandwich courses, student clubs are likely to increase in number and variety, especially if the necessary provision of hostels is made. Their provision is becoming increasingly important, if only to ensure proper conditions of living and studying.

The introduction of general studies into part-time courses will inevitably raise special problems, for example, the need of attendance on one day and two evenings a week if the technological syllabuses are to be properly covered. Conversion to block release courses or dilution of the standard of the final qualification appear to be almost the only choices available. We are of the opinion, however, that general studies are of such importance that provision for them must be made, no matter what special problems may arise.

10.6 Staff and Recruitment

The increase from about 60,000 to 83,500 technical college students between 1961 and 1970 will naturally require at least a corresponding increase of staff. However, because it is intended that there shall be a higher proportion of full-time and sandwich courses, a larger number of full-time staff will be required. In addition it should be realised that, as the level of the work rises, more staff are required for a given number of students. Table 10.3 shows the numbers of staff, from 1958, with the estimates for 1964 and 1970, based on the changes of numbers and emphasis indicated in Table 10.1.

The annual recruitment necessary to attain these figures is about 40 graduates in mathematics, physics or chemistry, 40 in the various branches of engineering or metallurgy and 7 graduate equivalents (A.M.I.E.E. etc.).

Recruitment of highly qualified staff is difficult at graduate level in many science subjects, and especially so in mechanical and production engineering.

Table 10.3 *Full-time Technical College Staff in Wales**

Year	Graduates			Graduate Equivalent	Others	Total
	Maths & Science	Tech-nology	Other	Technology		
1958	151	100	112	34	392	789
1959	182	116	125	43	433	899
1960	205	140	143	44	533	1,064
1961	228	163	169	642		1,202
1964	300	250	230	825		1,605
1970	450	400	350	1,200		2,400

* Note.—These figures make no allowance for the compulsory day release to the age of 18 years; the adoption of the 44 week year; block release for craft courses; increase in variety of sandwich courses; and full-time education in the first year of apprenticeship.

10.7 Research

Active participation in research is essential for all teachers engaged in advanced work. Good research is already being done by some of the lecturing staff who are particularly well-qualified for the examination of scientific and technological problems in relation to industry.

While the desirability of conducting research is generally recognised, the facilities in the colleges and the availability of time are not always such as to encourage sustained work. The rapid growth in technical education in the post-war years, which has involved the recruitment of many new members of staff, has inevitably meant that the proportion of teachers with the necessary interest in and ability to carry out research is not large. It is to be hoped that conditions in those colleges wishing to undertake work at an advanced level can be such as to attract staff of the highest calibre with an interest in research.

10.8 Laboratory Assistance

Recruitment of laboratory assistants is hampered in most cases by poor career prospects and inadequate salary scales. Some authorities have training schemes and are consequently better able to recruit laboratory assistants. In many cases, the total number of such employees in the service of an authority is too small to offer suitable prospects, and the situation remains unsatisfactory. Teachers in technical colleges need proper support by technicians, as do science teachers generally, if they are to operate efficiently.

The lack of clerical staff causes comparable difficulties inside the college and this also causes delay and irritation to outside bodies and employers.

10.9 Utilisation of Facilities for Advanced Courses

The report on *Technical Education in Wales* has drawn attention to the failure of properly qualified school leavers in Wales to utilise the facilities for advanced courses in the technical colleges. In spite of the increases shown in Table 10.2, there are still unfilled places, and this at a time when it is commonly believed that suitably qualified, prospective students are being denied higher education because they are unable to enter a university. Data from Chapter VIII indicates that there is a large number of pupils who do not qualify to enter a university. They are nevertheless qualified and suitable for technical college courses, and could, by a less steep route, attain comparable technical qualifications if they were prepared to enter technical colleges.

10.10 Summary

The accelerated development of technical colleges since 1949 is likely to continue, with increasing emphasis on full-time and sandwich courses.

The proportion of the age group following technical college courses is lower in Wales than in England, and this has been so for very many years.

About 900 students are prepared for advanced studies each year by way of the Ordinary National Certificate.

The technical colleges are not producing enough technicians and craftsmen to provide the best support for the number of technologists already being produced in Wales, if these remained in Wales as technologists in industry. On the other hand, it is apparent that most of these technologists find employment outside Wales.

Effective courses in general studies can assist in establishing the balance in education in technical colleges. There are difficulties of finding time for these studies in part-time courses but nevertheless we strongly support all attempts being made to establish and develop them.

A substantial increase in the rate of recruitment of well-qualified staff will be necessary over the next ten years.

There are serious problems arising from the low level of attainment in mathematics, science and English of some entrants.

We should like to see more research work carried out. To make this possible we would stress the need both of well-qualified staff and of adequate facilities.

There is a serious shortage of good laboratory assistants, but recruitment will depend on improvements in training, salary and promotion prospects.

Recruitment of students for advanced full-time and sandwich courses is less than the facilities warrant.

Chapter XI

THE UNIVERSITY OF WALES—NUMBERS OF ARTS AND SCIENCE STUDENTS

11.1 Introduction

The number of graduates likely to be produced over the next few years, in arts and sciences, is highly relevant to our inquiry.

Arts, in this context, includes subjects in Faculties such as those of Arts, Social Studies (including Economics and Geography), Education, Law, Music, Theology and Medicine.

The sciences will be considered under the two headings of the pure sciences and the applied sciences. One of the reasons for this is that the majority of the applied science graduates enter industry and contribute little as a source of school teachers, and the science staffing of schools depends almost entirely on graduates in pure science.

Pure Sciences, in this context, include the two groups of the physical sciences (comprising mathematics, physics, chemistry) and the life sciences (comprising geology, botany, zoology, bio-chemistry and micro-biology).

Applied Sciences, in this context, comprise all branches of engineering (including chemical and electronic), mining and fuel technology, metallurgy, and all branches of rural science.

We shall consider the present position in the University of Wales* with special reference to the numbers of those reading mathematics and the sciences as compared with those reading arts subjects.

11.2 Total Number of Full-time Students (Including Members of Departments of Education, Postgraduate Research Schools and those reading for Diplomas)†

Graph 11.1 gives the published figures over the quinquennium 1957–62 together with the planned numbers for the end of the succeeding quinquennium. However, the availability of places, particularly of science places, by the end of the quinquennium 1962–67 will depend on many factors, some outside the control of the University, as, for example, capital grants to supplement projected buildings (for laboratories, etc.), grants for academic staff, grants to permit expansion of technical and supporting staffs, and grants for equipment for teaching and research. Consequently, all attempts to forecast the future situation will depend, not only on the policy of the University and its constituent Colleges, but also on the provision of the means for its implementation. Again, the University degree schemes may well be changed, as indeed they have in other universities.

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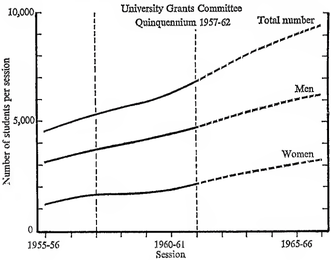
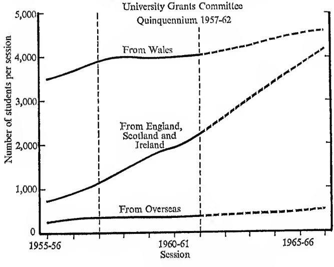
* The Council's remit is limited to the position in Wales.

† All data are taken from the Annual Reports of the University Council and from the University Calendar published annually.

Graph 11.1 FULL-TIME STUDENTS IN THE UNIVERSITY

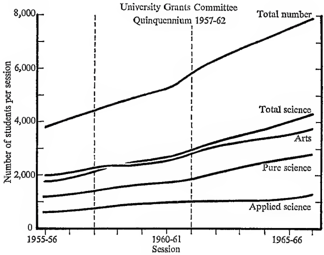


Graph 11.2 SOURCES OF FULL-TIME STUDENTS

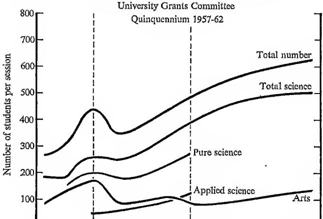


Graph 11.1 *Full-time Students in the University*
Graph 11.2 *Sources of Full-time Students*

Graph 11.3 UNDERGRADUATES

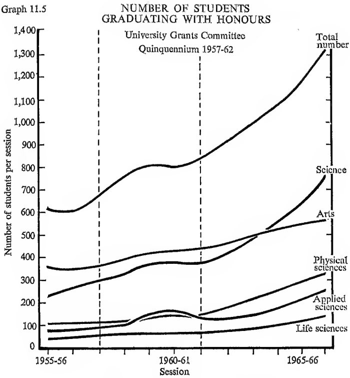


Graph 11.4 POST-GRADUATE RESEARCH STUDENTS



Note—Graphs to the right of 1962 are estimates.

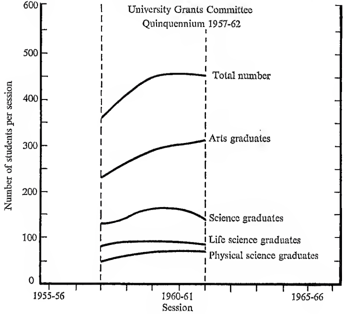
Graph 11.3 *Undergraduates*
Graph 11.4 *Post-graduate Research Students*



Note—Graphs to the right of 1962 are estimates.

Graph 11.5 Number of Students Graduating with Honours

Graph 11.6 DISTRIBUTION OF STUDENTS UNDERGOING TEACHER TRAINING



Graph 11.6 Distribution of Students undergoing Teacher Training

These figures show that there has been a steady expansion of the total full-time student population (the total for 1938–39 was only 2,779). Over the last five years the increase was 30 per cent, and the further increase expected over the next quinquennium is 35 per cent, giving a total increase over the ten years of 76 per cent. The ratio of numbers of men to women is altering, although slowly.

Graph 11.2 shows a steady reduction in the proportion of students from Welsh schools. If present trends continue the next quinquennium will see a still higher proportion of students from outside Wales in the University of Wales.

11.3 Distribution of Students

11.3.1 *Total Number of Undergraduates*

A negligible change has occurred in the proportion of arts to science in the quinquennium 1957–62 (see Graph 11.3). The pure science percentage (of the total number of undergraduates) increased only from 32 to 34 per cent while the applied science percentage remained at about 17 per cent. The next five years might, however, show an increase of up to 10 per cent in the proportion of science to arts, but the proportion of pure science students may well rise to 36 per cent while that of the applied science numbers may, if anything, fall.

The ratio of numbers of men to women is, understandably, much higher in the case of pure science students (4 to 1) than for arts students (7·3 to 1). The number of women in the applied sciences has increased slightly, but is still small (1 woman to every 24 men in 1961–62).

11.3.2 *Postgraduate Research*

Graph 11.4 shows, as perhaps might be expected, a preponderance of science students, and also indicates a remarkable peak for the year 1957–58, particularly as far as postgraduate students in arts are concerned; the number of these students for that session was substantially more than that for the previous session and even double that for the subsequent session. There are, however, reasons for believing that this isolated 'peak' was due to the influence of certain extraneous factors such as the provision of State Studentships (from October 1957) and the prospective ending of National Service (about 1958). Consequently, it would be unwise to regard this particular and ephemeral increase as in any way representing an academic trend. A slight 'hump' is also reflected in the curve for pure science. Accordingly, these abnormal increases for 1957–58 may well be ignored in attempting to assess the general trend. Bearing this in mind, it would seem that the ratio of the number of students in the sciences to that in the arts has been more than doubled over the last quinquennium and this probably represents a more realistic assessment of the trend in postgraduate studies.

The ratio of the numbers of men to women amongst the postgraduate students has doubled (from 5 : 1 to 10 : 1), again through the influence of scientific studies; the percentage of women research students in the arts is 30 per cent, but in the pure sciences only six per cent and in the applied sciences only two per cent.

The figures for all kinds of full-time students (but excluding diploma students and teachers in training) show a 10 per cent increase in the ratio of the number of science students to that of arts over the last five years, and a further 10 per cent increase is expected in the next quinquennium. It should be realised that this increase is almost entirely due to the large increase in the post-graduate student numbers in science rather than to any changes in the under-graduate population.

The next quinquennium 1962–67 may well see a marked increase in the number of M.Sc. students as a result of the Department of Scientific and Industrial Research policy of supporting graduates for formal studies leading to M.Sc. degrees as well as continuing their former schemes of maintenance grants for research students taking courses leading to M.Sc. or Ph.D.

11.3.3 *Students in University Departments of Education*

Table 11.1 *Students taking the Course for the Teacher's Diploma in Education*

Year	1957–58	1958–59	1959–60	1960–61	1961–62	1966–67
Total Number of Entries (A)	360	392	448	451	452	580
Men as Percentage of Total	62	61	65	62	58	
Women as Percentage of Total	38	35	35	38	42	
*Number of Diplomas in Education gained	336	377	409	415	395	
Total Entries (A) expressed as a percentage of Number of Students graduating in the previous Year	36	37	38	33	34	24

* The difference between the figures in this row and those in the first row is accounted for mainly by the numbers of those who were granted a Certificate in lieu of a Diploma.

Entrants to the Teacher's Diploma courses are normally graduates other than those in professional subjects, for example, in certain applied sciences and archaeology, law, medicine and theology; since the published figures for graduations do not permit the separation of all requisite data the entries are expressed as a percentage of the total number of graduates for the previous year.

Table 11.1 shows that there has not been a very large increase in the number of Diploma students. There is also very little significant change in the proportion of men to women.

An interesting result is that, over the five years 1957–62, rather more than one-third of all those students who qualified for an initial degree have been entering these Diploma courses. In view of the large variety of occupations and professions with a high demand for graduates today, this proportion (more than one-third) cannot be regarded as entirely unsatisfactory. The quality of the entrant, however, is a factor which we shall have to consider later.

11.3.4 *Comment*

There has been no marked change in distribution as between arts and sciences in the *overall* student population, numbers being approximately equally divided between arts and science. As these can virtually be regarded as separate specialisations, it would be of interest to know how much knowledge of arts subjects is acquired by the science student and how much background for the understanding of science by the arts student, from the point of view of a balanced education.

Among postgraduate students there is a distinct preponderance of science over arts students. With the increase in numbers of postgraduate students (the proportion of postgraduate students to undergraduates rising from 7·4 per cent to 9·5 per cent in four years), this difference may well have an effect on the life of the University, because postgraduate students are the senior students. While the majority of the pure science postgraduate students go into industry, nevertheless a small number will enter the teaching profession, and there in all probability take up posts of 'special responsibility'.

The undergraduate student population has increased by 30 per cent over the last five years. In that time the number of Diploma candidates has increased by 26 per cent and the corresponding number of Diplomas awarded by 18 per cent. This may well be a reflection of a deterioration in the academic standard of students entering the Departments. Over the last quinquennium, the number who entered annually was rather more than one-third of the number who obtained an initial degree. In view of the wide present-day demand for graduates this fraction cannot be considered unsatisfactory. However, no allowance has been made at this stage for the qualifications of students who apply to enter Departments of Education after graduation, but this aspect will be considered later.

11.4 Graduations from the University of Wales

11.4.1 *Numbers of Students Qualifying for an Honours Degree*

The number of honours graduates over the quinquennium 1957–62, together with an estimate for the last year of the following quinquennium, are given in Graph 11.5. It should again be emphasised, as indicated above in Section 2, that the approximate estimate of the numbers graduating in 1966–67 is based on the collective estimates of the constituent Colleges and Medical School of the University on the assumption, outlined above, that facilities will be provided for implementing the recent planning policies. Further, the pass degree scheme is undergoing revision in many universities, and in Wales may be replaced by a General Degree or General Honours scheme.

Graph 11.5 shows that arts graduates predominated in the honours schools over the quinquennium 1957–62 but that the position is expected to be reversed by the end of the present quinquennium. Even then, the graduates in arts are expected to comprise at least 42 per cent of all the honours graduates.

Graduates in physical sciences are nearly half the number of those in all the sciences; they are approximately twice as many as those in the life sciences.

It is now interesting to examine the breakdown of the number of honours graduates into the various subjects, particularly when considering the supply of graduates for various teaching needs.

Table 11.2 *Honours Graduates*

Year	1957–58	1958–59	1959–60	1960–61	1961–62	1962–63	1966–67†
Mathematics	14	21	31	26	44	38	60
Physics	51	53	62	50	43	76	120
Chemistry	61	49	65	75	80	79	160
Geology	20	24	20	16	17	24	30
Botany	22	29	25	25	27	39	45
Zoology	33	35	34	48	41	56	85
English*	56	59	65	74	62	74	—
History*	62	78	81	78	76	90	—
Engineering	34	38	61	63	62	64	140
Chemical Engineering	5	10	23	24	20	18	40
Metallurgy	19	19	23	19	11	20	35
Mining	5	5	6	4	3	3	10
Rural Sciences	41	41	45	47	41	42	50

* Including Joint Honours.
† Estimated figures.

The data for the quinquennium 1957–62 and estimates for the end of the following quinquennium are given in Table 11.2. It should be realised that little significance can be attached to variations from year to year in this context of the individual subjects, particularly for the earlier years; but the distribution is expected to become stabilised towards the end of the next quinquennium when it is thought that most departments will be working to the limit of their capacities.†

11.4.2 *All Graduates—(Honours and Pass)*

Table 11.3 gives the data for the quinquennium 1957–62, and shows that a small overall percentage increase has occurred in the proportion of science graduates to arts graduates. As for forecasting the trend in this next quinquennium, the increase in the proportion of science graduates is expected to be accentuated (see also the Advanced level results); in fact, the relative proportions of arts and science graduations is likely to be reversed in the ten years from 1957–67.

The estimate for 1966–67 is of course subject to the provisos already indicated. Even so, estimates which are based on the implementation of University policy are at least consistent with the 'massive swing towards science' in the sixth forms of grammar schools reported during the last six years.†

11.5 University Departments of Education

11.5.1 *Proportion of Science to Arts*

Graph 11.6 gives the distribution for the quinquennium 1957–62 of students following courses for the Teacher's Diploma in Education of the University of Wales. Arts students are usually qualified in modern languages, classics, history and geography; while science students have usually graduated in the physical or life sciences or in mathematics.

The graph shows that, throughout the quinquennium, about twice as many have graduated in arts as in science. From the point of view of the potential supply of teachers for secondary schools this proportion is not unsatisfactory, but, in view of the 'massive swing towards science', the total numbers may still prove insufficient.

It would be misleading to group all science students together, particularly from the point of view of the actual demands for teachers in the various branches of science in the secondary schools. For example, a graduate who is qualified in the life sciences may have had little training in mathematics or in physics beyond Advanced, or even Ordinary, level and he would therefore not be suitable for teaching mathematics and physics, subjects in which there is at present a serious deficiency in the numbers of graduates available. At the same

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* On the basis of the scheme of planned university expansion prior to the appearance of the Report of the Committee on Higher Education.

† See report of Welsh Grand Committee 1962.

Table 11.3 *All Graduates*

Year	1957–58	1958–59	1959–60	1960–61	1961–62	1962–63	1966–67
Total	1,061	1,171	1,373	1,337	1,442	1,545	2,600
All Arts	568	610	647	657	749	736	1,200
*All Science	493	561	726	680	693	809	1,400
Arts as % of all graduating	54%	52%	47%	49%	52%	48%	46%
Science as % of all graduating	46%	48%	53%	51%	48%	52%	54%
Pass Degree in Arts	144	191	212	237	306	230	630
Pass Degree in Science	185	232	327	295	298	344	625

* Not broken down, in the published figures, into pure and applied sciences.

time, it has been shown that there is an overall deficiency of science teachers, whether qualified in the physical sciences or the life sciences.

It is, however, more than a question of numbers. It has been shown in Chapter VII that there is a shortage of teachers with high qualifications in science and mathematics as compared with those teaching arts subjects. It is necessary therefore to analyse the data illustrated in Graph 11.6 in terms of the detailed qualifications of those students entering the University Departments of Education.

11.5.2 *Analysis of Science Qualifications*

THE PHYSICAL SCIENCES

For reasons stated previously, it is of interest to consider the physical sciences separately. The breakdown of the numbers taking Diploma courses in education for the quinquennium 1957–62 and who have graduated in the physical sciences is given in Table 11.4.

Table 11.4 *No. of Graduates in Physical Sciences who pursued the Teacher's Diploma Course in Education*

Year	1957–58	1958–59	1959–60	1960–61	1961–62
Total Honours Graduates in the Physical Sciences	23(104)	27(126)	30(123)	25(158)	30(151)
Mathematics	5(15)	4(14)	8(21)	8(31)	8(26)
Physics	7(33)	11(51)	15(53)	14(62)	15(50)
Chemistry	11(56)	12(61)	7(49)	3(65)	7(75)
* Total Pass Graduations in the Physical Sciences	20(170)	26(188)	36(235)	38(230)	33(256)

* A graduate may have qualified in more than one subject.

The numbers in brackets represent the total number of graduations obtained in the previous year. The numbers in brackets in the last row, however, are subject to a small error (of a few per cent) due to unpublished cases of overlapping, that is, honours candidates also taking pass degrees, and pass candidates taking more than two subjects. While no importance need be attached to year-to-year variations a general trend could be significant. If we bear in mind the importance of the teaching of mathematics, graduates in any of these three physical sciences (because of their mathematical background) can be regarded as approximately interchangeable, as far as teaching below Ordinary level in secondary schools is concerned; and it follows that we can consider the group as a significant whole in this context. This would also apply, to a large extent, to graduates in the applied sciences. Table 11.4 (first row) shows that over the quinquennium there has been no important change in the proportion of all the honours graduates who entered the University Departments of Education (about 20 per cent). The proportion, however, appears to vary with the subject; in mathematics and physics about one-third of those who graduated entered on a Teacher's Diploma course while in chemistry the proportion is much lower. The figures for the pass graduates show even greater consistency; about 13 per cent of those who graduated with pass degrees in the physical sciences undertook teacher training. Of the 60 or so graduates in physical sciences who obtained the Diploma in Education, about half were pass graduates.

It is relevant to consider the availability of trained teachers with good honours degrees in the physical sciences, since these are usually required for sixth form work. Indeed for advanced work, the qualifications in the particular separate subjects are highly important, especially in mathematics. The interchangeability of teachers is thus considerably reduced because of the degree of specialisation now required in the sixth forms of grammar schools. When one takes into account the grade of honours obtained by the graduates included in Table 11.4 a situation is disclosed which cannot be regarded as entirely satisfactory. In evidence submitted to Council, one Department of Education stated that *no graduate with first class honours either in mathematics or in any of the sciences took the courses in teacher training in any of the years of the quinquennium.* Further, during that period, no graduate with an upper second in chemistry took the Teacher's Diploma course while in physics only one did so, though in mathematics there were five. Of a total number of 75 science graduates who entered that education department over the quinquennium, 69 (or 92 per cent) had lower second, third class or pass degree qualifications only. Of 31 honours graduates over the quinquennium only 20 per cent had even upper seconds, there being no firsts.

THE LIFE SCIENCES

Table 11.5 *No. of Graduates in Life Sciences who pursued the Teacher's Diploma Course in Education*

Year	1957–58	1958–59	1959–60	1960–61	1961–62
Total Number of Honours Graduates in the Life Sciences	58(65)	51(77)	45(92)	48(82)	35(89)
Total Number of Pass Graduations in the Life Sciences	26(110)	29(119)	44(143)	48(141)	47(140)

It can at once be seen that a much higher proportion of these graduates took a Teacher's Diploma course. Even so, the proportion of the honours graduates fell from 89 per cent to 43 per cent throughout the quinquennium; the proportion of pass degree students rose from 24 per cent to 33 per cent during the same period. It must be accepted that this represents a significant trend in the qualifications of those entering Teacher's Diploma courses.

The trend is also illustrated by considering specific figures from the particular Department of Education referred to above. Over the last quinquennium, out of 62 graduates in the life sciences, 56 (90 per cent) had lower second, third class or pass degrees; there were only 6 with upper second class honours and no firsts. These proportions are practically the same as for the physical sciences.

11.5.3 *Place of Science*

In one University College a much appreciated course on the history and philosophy of science is given by a member of the Department of Philosophy. It is true, however, that the majority of those electing to take it are science graduates. In one of the papers on the history of education an optional section is included on science. In another College a short course of lectures was given a few years ago by one of the members of staff on 'The Nature and Limitations of Science'.

Some evidence we received was critical of the lack of opportunity for students in the University Departments of Education to familiarise themselves with effective methods of work in school laboratories. Enquiries revealed that the position is as follows.

As far as practical work is concerned, each education department has a small laboratory where science students spend about two hours a week. An attempt is made to give the students some experience in performing the type of experiment which they will later have to carry out in school. The tutor attempts to give the members of his group some insight into the work of organising and costing involved in the equipping of a school laboratory. However, there is evidently a need for extended accommodation since, in some cases, it is not possible to accommodate more than four or five students at a time. Moreover, the provision varies with the particular science subject. For example, a College may be relatively well-equipped as far as chemistry is concerned, but not in physics or biology.

To sum up; it seems that in recent years there has been a small but welcome attempt to pay attention to the practical aspects of the science teacher's work, but it is our opinion that these aspects require more emphasis in the training of science teachers. It is essential that the need for adequate accommodation and technical help should be met.

11.6 University Staffing

The main source which supplies graduate teachers for schools is of course the university; this is the same source which attempts to meet the demands of industry and government research establishments, as well as its own demand for university teachers. It is of interest therefore to consider the numbers of university teachers over the last quinquennium in arts and science; and the planned requirements over the next quinquennium. We again emphasise that this estimate is subject to the provisos referred to earlier.

The numbers of full-time teaching staff in the various categories in the University of Wales are given in Table 11.6 for the quinquennium 1957–62 together with the estimates based on the planned expansion of the University. The numbers are deduced from the information given in the University of Wales Calendars.

Inspection of the Table 11.6 shows that the numbers for both arts and science have steadily grown, and will continue to do so but at an increased rate; the numbers of staff in 1966–67 will be approximately double the number in 1957–58. Although in our remit we are limited to Wales, there is reason to believe that the position will be similar to that in the United Kingdom as a whole; that is, over the next five years there may well be about 50 per cent

Table 11.6 *University Teaching Staff*

Year	1957–58	1958–59	1959–60	1960–61	1961–62	1966–67
Total Staff	609	626	675	772	832	1,304
Total Arts	359	369	391	444	468	673
Total Science	250	257	284	328	364	631
Pure Science	160	166	183	207	225	408
Applied Science	90	91	101	121	139	223
Arts Staff as % of total Staff	59	59	58	57·5	56	51·6
Science Staff as % of total Staff	41	41	42	42·5	44	48·4
Pure Science Staff as % of total Science Staff	64	65	64	63	62	65
Applied Science staff as % of total Science Staff	36	35	36	37	38	35

increase in the number on the staffs of universities. However, the distribution as between science and arts will change somewhat; the total science proportion will rise from 41 per cent in 1957 but may still be less than 50 per cent in 1966–67. The proportions of pure and applied science are unlikely to change significantly over the two quinquennia.

Table 11.7 *University Staffing Requirements in Physical Sciences*

Year	1957–58	1961–62	1966–67
Total Full-time Staff in the Physical Sciences	93	140	243
Mathematics Full-time Staff	34	53	95
Physics Full-time Staff	29	41	81
Chemistry Full-time Staff	30	46	67

In view of the critical position in regard to the supply of teachers in secondary schools, it is of interest to consider whether the output of graduates from the universities is numerically sufficient to meet the demands of secondary schools as well as their own staff requirements, together with all the other demands, including those of colleges of technology, industry, administration etc., and this will be considered further in a later chapter.

Table 11.7 gives the numbers in the physical sciences at the beginning and end of the two quinquennia. If we consider mathematics, this table shows that, even if we do not take retirement into account, about eight mathematics graduates will be required annually for the University alone.* Comparable figures for physics and chemistry are eight and four. An estimate of the average annual demand for graduates in all the pure sciences over the quinquennium 1962–67 is 37, and for applied science it is 17.

The seriousness of the staffing position is illustrated by the figures in Table 11.2. This table shows that in 1961–62 the total number of honours graduates (of all classes) in mathematics was only 44. Presumably only those with high honours degrees would be recruited to a university post. For 1961–62 there were seven students with first class honours. This is to be compared with the average annual requirement of eight for the University Mathematics Departments alone, to which should be added the much larger number sought by all the other interests competing for such graduates.

11.7 Summary

In 1963, it was government policy that there should be by 1967 an increase of 76 per cent in the total student population of the universities over the preceding ten years.

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* We must point out again the difficulty of considering the Welsh scene in this context rather than the United Kingdom as a whole. Staff for the University of Wales, to judge by past experience, will of course be heavily recruited from the rest of the United Kingdom; equally, Welsh graduates will be recruited to English and Scottish Universities. We must therefore assume a measure of equilibrium and can then regard Wales as a viable unit.

In the *overall* student population, numbers are approximately equally divided between arts and science. There is, however, a distinct preponderance of science over arts amongst postgraduate students. This may well have an effect on the general life of the University.

About one-third of the number who obtain an initial degree enter a Teacher's Diploma course annually. This proportion is satisfactory, when one considers the other strong demands for graduates.

It is a serious matter for the schools that so few graduates with good honours degrees in mathematics and science are entering the University Departments of Education.

There has been a small but welcome attempt in these Departments to pay attention to the practical aspects of the science teacher's work, but we are of the opinion that these aspects require greater emphasis.

To meet the planned expansion of the University, it is estimated that the numbers will be doubled over the ten-year period 1957–67.† As it is reasonable to suppose that those appointed to university posts should have firsts or upper seconds, it is alarming to find that the number thus required, for example, in physics will be a high proportion of those who will be graduating with such honours degrees, and in mathematics the number required will (on reasonable estimates) actually exceed the number graduating. When it is realised that good honours graduates in science are also required by research establishments (government and industry), the outlook for the schools is grim.

While it has been generally appreciated in recent years that there is a shortage of science teachers in our schools, we do not think that the extreme seriousness of the position has been realised. Further, on present evidence this seriousness is likely to increase rather than diminish in the immediate future.

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† Early in 1964 universities are already engaged in accelerating their programmes of expansion.

Chapter XII

ADULT EDUCATION

12.1 Science in Extra-mural Adult Education

It is clearly of the utmost importance in a democratic and highly industrialised society such as ours that, quite apart from the formal provision made for the rising generation in schools, technical colleges and universities, there should be a general awareness amongst the adult population of the proper significance of science and of its place in contemporary society and culture. To some extent, this awareness already exists and there can be little doubt that modern mass means of communication are today contributing on a considerable scale to the spread of scientific knowledge, though much of this knowledge will be superficial and inexact. Television programmes, in particular, play an increasingly important educational role, and the efforts that are now being made, both by the B.B.C. and by the Independent Television Companies, to present planned courses of study for adults, in science as in other subjects, deserve the highest praise. These developments, however, in no way lessen the responsibility of the traditional forms of adult education or detract from their importance. University extra-mural and W.E.A. classes have, more than ever, perhaps, a vital task to perform. At one time they served a remedial purpose for those whose general education had been inadequate and incomplete. This function they still fulfil, but, in the context of our contemporary situation, disciplined courses of study for adults should also help to correct the imbalance of a formal schooling which for many has entailed too early a choice between science and arts and which as a result is in danger of dividing our society into two mutually exclusive cultural camps.

One cannot speak of a balance of studies for the individual student in adult education as one can in the formal programme of education pursued in school or college. But one can legitimately speak of a balance between the arts and sciences in the general provision made by the various adult education agencies, such as university extra-mural departments, the W.E.A. and the local education authorities. It is with this latter balance that we are concerned here. It requires, we believe, some rectification.

In Wales, today, the sciences play a very lowly part in adult education. Out of a total number of 789 courses provided by the University Extra-mural Departments and by the W.E.A. in 1961–62, only 41 dealt with the physical and biological sciences.* That a mere 5·3 per cent of the formal educational provision for adults in Wales is devoted to science can hardly be regarded as satisfactory. We have even less cause for satisfaction when we compare our position with that of other parts of the United Kingdom. An analysis of the 1961–62 Report of the Universities' Council for Adult Education reveals that science courses in England, Scotland, and Northern Ireland during the session accounted for 13·4 per cent, 11·7 per cent and 19·1 per cent respectively of the total programme of the university extra-mural departments.

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* University of Wales Extension Board Annual Report 1961–62.

There are, no doubt, many reasons for the present unsatisfactory state of affairs in Wales.

Until quite recently there was a measure of truth in the statement that our concept of education tended to emphasise the humanities. There was, therefore, only limited opportunity for developing an interest in science amongst the adult population outside school and college. In the Welsh-speaking parts of Wales the language itself has retarded the growth of scientific studies, not because Welsh is incapable of communicating science but because well-qualified teachers able and willing to teach science in Welsh were rare. It is still difficult to obtain competent tutors for science classes in Welsh, though the position is improving, and it is only fair to add that there have been some outstandingly successful Welsh science tutors in the past.

A more fundamental consideration, applicable to Welsh and English-speaking areas alike, has been that the study of a science, and of the physical sciences in particular, unless it is conducted at a very elementary level, presupposes in the student some acquaintance with mathematics and with scientific method, and demands facilities for practical work. The needs of young adults would therefore be more properly and adequately met by science courses in technical colleges and institutes rather than in the traditional type of adult class provided by the universities and by the W.E.A. The whole ethos of the traditional adult education movement in Wales, as elsewhere in Britain, has been based on a profound conviction of the importance of liberal studies, and the social purpose of many of the participants has lead them too readily to assume that the term 'liberal' excluded science. This is not surprising when one recalls that it took many years for general 'cultural' subjects, such as art and music, to win a place in the orthodox curriculum. Adult educationists in Britain have only just begun to realise that a liberal education today needs to be aware of the impact of science on contemporary thought and culture, and of its influence on the structure of industry, on the nation's economy, and on the very patterns of society. The realisation has come later in Wales than elsewhere.

This is not to say that no useful work has been done in science in Wales amongst adults. On the contrary, all four Extra-mural Departments have for many years past included scientific subjects in their programme, and so, to a lesser extent, has the W.E.A. The various College areas differ in background and in social conditions, but the biological sciences, have predominated in rural and urban areas alike, partly, it may be, because of their more obvious human appeal, and partly because they present fewer practical difficulties to the tutor. Subjects like botany and marine biology offer attractive possibilities for field work, and in the rural areas genetics and agricultural science have an immediate practical interest. Natural history and geology have proved particularly popular in some areas, geology notably in the Swansea area. A number of successful courses have been held in the physical sciences, though usually on rather general lines, such as 'The Development of Modern Physical Science', 'Space, Astronomy and the Beginning of Things', etc. Perhaps such general courses, or topics like 'Science and Everyday Life', 'Science and the World Around Us', and courses on the history of science, are the most one can expect under this heading within the traditional framework of adult education. But there have been one or two pointers recently to significant new developments. At Cardiff, for instance, there have been courses on 'Tensor Analysis' and 'Nuclear Theory'. In North Wales, courses have been held on

'Transistors and their Applications' and on 'Soil Science and the Use of Land'. These have been special courses, provided by the Extra-mural Departments concerned for special groups of industrial workers, and they represent a new form of service which extra-mural departments are being called upon increasingly to perform.

Formal adult education arises, and classes are provided, in response to an already existing demand. The demand for science classses in Wales at the moment is small. The problem would therefore seem to be whether a latent demand can be discovered and developed. There is some evidence, however, from courses already successfully conducted in various parts of Wales, and from the growing popularity of science programmes on television, that the public interest in science is increasing amongst adults of all ages.

Some tentative steps have already been taken to improve the position of science and add to the number of courses. At Cardiff a special sub-committee of the Advisory Committee for Tutorial Classes has been appointed to assist in the general development of science courses. At Swansea, seminars have been planned among the intra-mural staff to discuss suitable subjects which can be taught in extra-mural classes, to discover suitable and willing tutors and to examine the use that can be made of the laboratory facilities at the College. Aberystwyth has held a tutors' conference to consider problems of teaching science in extra-mural classes, and a similar conference was held some years ago under the auspices of the Merioneth L.E.A. in which representatives from Aberystwyth, Bangor and the W.E.A. took part. Cardiff has appointed a biologist to the full-time extra-mural staff, and Swansea expects that the recent appointment of a staff tutor in Industrial Relations will facilitate the organisation of courses providing up-to-date scientific information for professional scientists in industry. The Welsh Department of the Ministry of Education has shown an appreciation of the importance of adult science studies, and has included science teaching as a main subject of discussion in a conference of adult education tutors to be held during the summer of 1964.

12.2 Suggestions for Improvement

The study of science for adults may be approached in two ways: learning *about* science, its impact on modern thought and on society, its role in modern industry, etc.; and the formal study of a particular scientific discipline.

The first type of course is relatively easy to arrange, provided a suitably qualified tutor is available, but there are, as we have seen, serious practical difficulties in providing formal courses for adults in a particular science. Amongst the difficulties, a lack of suitable text books, and lack of access to laboratories, make it almost impossible to provide proper courses for adults who have no previous acquaintance with scientific studies. This applies especially to the physical sciences. The biological sciences on the other hand are more easily provided for, and this no doubt explains why they figure more prominently in adult education programmes at the moment.

There seems no intrinsic reason to suppose, however, that given suitable facilities, and well-qualified teachers, adults should not apply themselves to the serious study of both the physical and the biological sciences and of mathematics.

It would not be true to say that there is a lack of competent tutors in science, though no doubt their availability varies and there are difficulties in the Welsh-speaking areas of obtaining well-qualified tutors who are prepared to teach their subject in Welsh. The main responsibility for organising the teaching of science to adults must inevitably rest with the University Colleges, and many members of staff in the Science Departments of the Colleges, especially the younger lecturers, are only too ready to take classes when the opportunity arises. Teaching adults, however, often demands special methods of presentation in which university lecturers and grammar school teachers have little experience, and, moreover, it is clearly impossible for part-time tutors to undertake on any large scale the missionary work for science which is necessary at this stage. The only effective way to ensure that scientific studies are developed successfully amongst adults would seem to be by the appointment of full-time science tutors to the staffs of the Extra-mural Departments, who will have access to suitable laboratories where the students can carry out experiments for themselves.

At the present moment, there is only one full-time extra-mural science tutor in Wales. We note with approval that Cardiff has already appointed a biologist to the extra-mural staff, and that this appointment has quickly led to a marked improvement in the position of science in the programme. Whereas in 1961–62, 4·3 per cent of the extra-mural courses of the University of Wales were in scientific subjects, in 1962–63 the proportion had more than doubled and stood at nine per cent. This improvement was due almost entirely to a formidable increase in the number of science courses at Cardiff, where science now accounts for 15 per cent of the total.

We are therefore led to the conclusion that action on the following lines would considerably improve the position.

The University of Wales (through its Extra-mural Departments), the North and South Wales Districts of the W.E.A., and the local education authorities, should regard the expansion of facilities for science study for adults as a matter of urgency.

Particular attention needs to be given by the organisations concerned to the training of part-time tutors in the most suitable methods of presenting scientific studies to adults.

Appointments of full-time tutors in science might, with advantage, be made by Extra-mural Departments at Aberystwyth, Bangor and Swansea, and by the W.E.A. Districts in North and South Wales as soon as possible.

However, we are conscious of the fact that this expansion, like that in any other branch of education, is conditional upon the supply of qualified science teachers.

PART III
THE DEMANDS UPON THE EDUCATIONAL SYSTEM IN WALES

Chapter XIII

THE DEMANDS OF INDUSTRY, RESEARCH ESTABLISHMENTS AND ADMINISTRATIVE SERVICES

13.1 Modern Industrial Wales

In Chapter II we gave a brief picture of the development of industrial Wales. In this chapter we are mainly concerned with the requirements of industry for graduate (or equivalent) scientists and technologists.

If the pattern of industry in Wales today is compared with that of the period between the first and second world wars, a significant change is immediately apparent. In the twenties and thirties the Welsh economy depended largely upon a limited number of basic industries, in particular coal and steel. Nowadays, these industries form a much smaller percentage of the industrial employment, investment and activity in the Principality. This has resulted from the influx, both during and after World War II, of a large number of widely varying industries, mainly light in character. This influx has in general been welcomed on all sides as giving greater stability to the industrial scene and providing a more resilient Welsh economy to face industrial and economic setbacks. Nevertheless, steel and coal still play an important part in the industrial scene, but these industries have undergone revolutionary technological changes and compare favourably with similar industries in the rest of the world.

However, a closer examination of the position reveals some disturbing features which, unless they receive attention, may give rise in the future to industrial and social problems as serious as many of those faced in the past. For example, many industrial plants which have been set up in Wales in recent years consist almost entirely of production units. Several of these employ thousands of workers and contain the most up-to-date manufacturing machinery available, and there is no doubt that they have solved serious unemployment problems in many localities. Industry, however, is not concerned with production alone, but may be likened to a three-legged structure, in which the legs represent design (with all its technical implications), production and sales. Unless a proper balance exists between these three legs, an unstable structure results which may be unfitted to resist economic or industrial setbacks. Most of the large production units in Wales derive almost all their design, development, research and indeed senior executive stimulation from their respective headquarters. The latter, however, are usually located outside Wales. Relative to their size, these factories employ extremely few executives, either professional or managerial. Many of these factories do not contain even the nucleus of a design and development group, let alone a research section. There are certainly cogent reasons why sales sections should be located near the main commercial centres and why research sections should be placed near the main national centres of learning and scientific research. There is also a case for research sections being located near the production units in which problems arise and into which new ideas have to be fed. While some of these large factories are part of a science-based industry, in which scientific and technical research is carried out at central research laboratories, others are part of a more traditional industry, which has yet to take full cognisance of the need for research and the application of the results of research.

The future health of industry in Wales depends to a great extent on there being a sufficient proportion of managerial, technological and research personnel of the right quality within Welsh industry. There are reasons for believing that the present trends are directed towards a situation in which there will be an insufficiency of this type of managerial and professional content in many of our industrial units. Unless these trends are halted, industry in Wales may lose some resilience. We consider that this is a matter to which due attention should be given by both government and other agencies which are concerned with the attraction of industry to Wales and the distribution of industry within the Principality generally.

13.2 Distribution of Scientists, Technologists and Technicians

Any discussion must be prefaced by lamenting the almost complete absence of any statistical information on this subject. It has, consequently, been possible to make only the roughest estimate of the numbers, qualifications and relative distribution of qualified personnel as between industries, academic institutions, government establishments and nationalised bodies. In spite of the diversification which has taken place during the post-war years the Principality nevertheless contains a greater proportion of traditional, as compared with science-based, industries than does Great Britain as a whole. This can be seen by analysing the population from three different aspects.

Firstly, we may consider the population as a whole. During the census of 1961 a ten per cent sample was taken of the whole population in order to determine the approximate number of people in Great Britain with scientific and technological qualifications of approximately degree standard. An analysis of this ten per cent sample has recently been published; it shows that there are about 287,000 persons with these qualifications in Great Britain. If figures for Wales from this group are considered on the basis of a proportion of the total population, it would be expected that Wales would contain about 14,500 scientists and technologists, since its population is about one-twentieth of that of Great Britain.

Secondly, if we take the number of people in this technological group as being proportional to the total number of insured workers, given in the statistics of the Ministry of Labour, then the proportion for Wales now becomes 10,000 or one twenty-eighth of the total.

The third method of looking at this question is to consider an analysis of the employed population industry by industry, because the proportion of scientists in industry depends greatly on the type of industry. In this way it is found that the number of graduate scientists and technologists in Wales would be fewer than 8,000. (See Appendix VI.) This smaller number, compared with the two previous numbers, is an indication of the pattern of employment of scientists and technologists at graduate level in industry in Wales.

The different constitutions of industries, from the technological point of view, can be seen by contrasting the situation in two very different types of industry such as mining and quarrying on the one hand and vehicle production on the other. Appendix VI shows that mining and quarrying throughout Great Britain employ 737,000 persons, of whom only 4,200 are graduates (or equivalent). The vehicle manufacturing industry, which employs a comparable total number (894,000), includes among these as many as 13,341 who are scientifically qualified. Wales has only 2·5 per cent of this industry, but has 14·5 per cent of the mining and quarrying industries which employ a lower proportion of graduates.

There are, however, in Wales some industries, such as those of chemicals and plastics, in which the proportion of technologists and technically trained managers compares favourably with those to be found elsewhere in the United Kingdom. It is generally only such firms which offer advanced industrial careers to the young Welsh technologist and scientist; although it should perhaps be mentioned here that, in the opinion of several leading industrialists, university trained scientists appear to enter an industrial career at a distinct disadvantage as compared with the industry trained technologists.

Where, then, do the main opportunities for scientists and technologists lie in Wales? The indications are that, in relation to its population, the industrial opportunities for the scientist and technologist of graduate standard do not match the number potentially seeking them; in Chapter X a more detailed consideration of this question was given. It seems that the present situation involving, as it does, lack of opportunities in science is likely to be aggravated if the predictions of the Advisory Council on Scientific Policy regarding manpower are fulfilled. The number of posts with opportunities for scientists to work exclusively on research is limited in academic institutions and the opportunities in government and related employment in Wales are also relatively few. Undoubtedly, the future will bring demands for more technical skills in operating plant and maintaining its efficiency, but this is more particularly the part played by the skilled technicians rather than the technologists and scientists. Here again it is difficult to get figures even to assess the present position, let alone predict the future. It does appear at present that Wales is not generally lacking in opportunities for skilled technicians, but there are, of course, some exceptions. (We would emphasise again that, in the absence of detailed figures, the above observations are based on an overall assessment of the position regarding all scientific and technological graduates.)

Industrial comments from some quarters have indicated that in certain parts of Wales recruitment of the right quality of scientists and technologists, particularly from Welsh institutions of higher education, is for various reasons very difficult. However, this has not been a general criticism and probably applies to certain restricted technological and scientific fields where the number of vacancies is not great.

There is another aspect of the question of recruitment of scientists and technologists and of the creation of opportunities for them. This concerns the industrial and technological atmosphere or background of the particular posts to be filled. There is little doubt that a modern science-based industrial environment, in which the results of scientific research and development can be seen in application, has important industrial and educational implications and effects. The research worker, for instance, is greatly helped and stimulated by association with others working in kindred fields (indeed, therein lies the attraction of working as a post graduate research student in a lively and vigorous laboratory). A post in a region containing many active research and development establishments or laboratories can be a much more attractive proposition to the young scientist than a post at the same, or even much higher, salary in a more isolated community. There are also educational effects produced by active science-based industrial research communities. One thinks here of the scientific and industrial environment of a place like Hatfield, for instance, where, apart from the mutual support and stimulation derived from the proximity and interaction of varied industrial and scientific establishments and research laboratories, the educational institutions in the area derive benefit in stimulation and also in the supply of students and teachers of the right quality.

The position in Wales concerning government scientific and technical establishments is depressing. For example, there are no large service establishments doing scientific research requiring highly qualified scientists comparable with those found in other parts of the United Kingdom, such as the Atomic Weapons Research Establishment at Aldermaston, the Services Electronics Research Laboratory at Baldock and the Royal Aircraft Establishment at Farnborough. A similar situation exists in the research laboratories of nationalised industries. The main research laboratories of the National Coal Board are at Cheltenham, those of the Central Electricity Generating Board at Leatherhead, of the Post Office at Dollis Hill and of British Railways at Derby. There are no Department of Scientific and Industrial Research establishments in Wales comparable with the National Physical Laboratory and the National Chemical Laboratory in London, and the National Engineering Laboratory in Glasgow.

It is estimated that government research establishments in Wales employ fewer than 200 people of all grades, ranging from laboratory assistants to university graduates. These people are employed in a number of establishments which are scattered throughout Wales and do not have even the mutual support and stimulation of close proximity to each other; neither do they provide the incentive and impact of providing an environment attractive to industrialists or others seeking a scientific climate in which to locate establishments. Unless the situation is changed, any young person in Wales seeking a career in the Scientific Civil Service (which employs over 15,000 people in the United Kingdom) must realise at the outset that it will almost certainly be necessary to leave Wales in order to pursue a significant career, with little or no chance of being able to return and still to follow that career later on.

This is not to say that leaving Wales is not good in the initial development of such a career, but it is unfortunate that so few opportunities exist for Welshmen in the Scientific Civil Service to return to the Principality. In this respect Wales compares particularly badly with Scotland, where, in addition to two major D.S.I.R. establishments and several minor D.S.I.R. out-stations, there are several other government, civil and defence research establishments providing altogether employment for well over a thousand scientific and technical grades. Much pressure has been put upon the government in recent years to remedy this situation in Wales, but so far without any significant success. The situation is made worse by the almost complete absence from Wales of the very large industrial research establishment. Few of the many industrial and academic research laboratories in Wales are of any great size and it is estimated that the total research population of graduates employed in them is probably not more than 2,000. This figure of course does not include those persons possessing similar qualifications who are employed in a managerial or executive capacity within industry, administration or elsewhere. In England, particularly in the southern part, many large industrial laboratories, each employing hundreds of graduates, have demonstrated their value to industry and the community, not only for their direct results but also in their indirect local impact through education and social stimulation. This is particularly true of the research establishments such as those maintained by the large electrical concerns and the government. The difficulty some Welsh firms have quoted, in attracting scientists and technologists of the right calibre to the vacancies which they have, may stem directly from the fact that qualified persons of this kind are not anxious to work in a region where opportunities for close and convenient association with other industrial research scientists are limited, as they are believed to be in Wales, particularly in certain areas. This is a matter which requires further attention.

13.3 The new Industrial Pattern and its Educational Demands

If the general situation described above continues, it would appear unlikely that there will be any significant change in the pattern of employment of scientists and technologists, either in industry, academic institutions or other establishments in Wales in the immediate or foreseeable future. As industry grows we may expect a steady increase in the demands of Welsh industry for trained technicians and a much smaller, but nevertheless increasing, demand for scientists and technologists.

There is another point which we might mention at this stage. It has long been felt that university research science departments have too high a proportion of scientific staff of what might be termed research superintendent status, with far from adequate supporting staff of technicians and executives. If this situation were ameliorated then there would immediately be created a further demand for highly skilled and qualified technicians. Such an improvement in the conditions of university work could result in attracting to the university many scientists who now take up research posts elsewhere. Moreover, many science graduates leave Wales (and indeed Great Britain) to work in other countries where such research support is more readily forthcoming.

There is little ground for thinking that there will be any large increase in the demand in Wales for scientific and technologically qualified persons for work in industrial research laboratories. Undoubtedly, a number of further industrial units are likely to be situated in Wales and it is probable that many of those already here will continue to grow, but in consequence of the imbalance between the numbers of executive and technological workers and those employed purely in production and maintenance there does not seem to be much cause for optimism.

On the question of unfilled vacancies for scientists referred to earlier it may indeed be that in certain circumstances industry is stipulating a level of qualifications inappropriately high or excessively specialised for those whom it seeks to recruit. Payne* states that industrialists in many parts of Britain are critical of the products of our universities, preferring often to recruit their technologists through employing and training student apprentices whom they consider to be of more practical use and immediately beneficial to industry when they have completed their training. Such a procedure puts the scientists and technologists graduating direct from a university into industry at a disadvantage compared with industrially trained technologists. We have also received some evidence from industry which indicates that many graduates in their raw state when leaving university have an elevated opinion of their value to industry, an opinion which has probably been induced by the national shortage since the war. It should be realised however that the university graduate scientist is not 'trained' for any type of industrial post. He will be expected to have acquired a knowledge and understanding of fundamental scientific principles which, in spite of ignorance of modern industrial techniques, method and procedure, nevertheless should provide him with an adaptability, open mindedness and a fuller appreciation of possible scientific development. A disadvantage in comparison with the industry trained technologist is inevitable initially, but this need not be permanent. At the same time many criticisms are levelled against industry for the inappropriate use of graduates once recruited. Thus there seems to be considerable need for closer cooperation between industry and the universities in order to ensure that general problems of industry with regard to the recruitment and deployment of young graduates are recognised and appreciated.

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* G. L. Payne, *Britain's Scientific and Technological Manpower*, 1960. Oxford University Press.

Although from the preceding analysis it does not seem likely that there will be any sudden large demand from Wales itself for an increase in the output of scientists and technologists from Welsh educational establishments, obviously these establishments should contribute towards the supply of such persons in the United Kingdom generally. The need for more scientists and technologists has been stressed in the report on manpower of the Advisory Council for Scientific Policy.

13.4. Annual Demand for Graduates in Science and Technology

Apart from teaching (which we shall consider in the next chapter), graduates in science and technology are, of course, required in various professions, such as those in central and local government. These are included in the overall figure of 14,800, details of which are given in Appendix VI.

As we have mentioned, there is no detailed information on the numbers and distribution of graduate scientists in Welsh industry, and we have given three estimates of the position. Taking the lowest figure of 8,000, this would represent a minimum annual requirement of 200, if we assume 40 years to be the average working life. However, we believe the period of 40 years is far too long, because scientists and technologists often move to other fields, and an effective 'working life' of one-third of this period would not be unrealistic. On this basis, the annual recruitment would be correspondingly higher. It is estimated that the number of graduates in science and technology at present in research laboratories in Wales is between one and two thousand, which would represent, as a conservative estimate, an annual requirement of something between 50 and 150.

On the evidence available we consider that, apart from teaching, there will be a need in Wales for an estimated annual number of between 200 and 350 graduates in science and technology. However, in view of the existing degree of mobility, the 'working life' of a scientist in a particular research organisation might well be such that the annual requirement would be three times the above figures, over the next five to ten years.

13.5 Summary

Although the Welsh industrial scene appears relatively healthy from the point of view of diversification and modernity, there are good reasons for thinking that in Wales there is a serious imbalance between the number of senior scientific and technological people and other employees engaged in industry. This, it would seem, can only be remedied by the location of more design, development and research centres in industry in Wales, and the employment of more managers with scientific and technological qualifications in industrial management.

In comparison with the country as a whole, Wales is sadly lacking in large research establishments, particularly in the physical and engineering sciences. The opportunities for graduates in Wales to follow a career in scientific or technical research are very limited and the facilities appear quite inadequate to satisfy the output of Welsh educational establishments.

Consideration should be given to the setting up in Wales of a government research establishment or establishments of significant size.

There is a need for more technical staff to support scientific research workers in academic institutions in Wales.

There is a need for fuller cooperation between educational establishments responsible for producing scientists and technologists with higher qualifications and industry itself, to consider together questions such as those concerned with the full deployment of the young graduate in industry.

There is a need for a survey of scientists and technologists in Wales, particularly in relation to their employment and distribution within the Welsh industrial, administrative and academic scene.

The total research population of graduates employed in Wales in industry and other laboratories is probably not more than 2,000.

A conservative estimate of the annual demand in Wales for graduates (or equivalent) in science and technology in the immediate future, quite apart from teaching, is between 200 and 350.

Chapter XIV .

DEMANDS OF THE EDUCATIONAL SYSTEM

14.1 Introduction

In earlier chapters reference has repeatedly been made to the need for increasing the number of staff with appropriate qualifications in science and mathematics in primary and secondary schools, technical colleges, training colleges and in the universities. This increase is particularly necessary in secondary schools, to remedy serious existing shortages, but at all stages of the educational system the policy of planned expansion will require a further substantial increase in the number of teaching staff. In this chapter an attempt is made to assess the number of teachers that will be required in the next decade to enable science and mathematics to make the full contribution to a balanced education envisaged in this Report. The needs of each of the major sections of the educational system will now be considered in turn.

14.2 University

Table 11.6 shows the estimated needs for various categories of staff in the University of Wales in the quinquennium 1962–67. During this period, on the basis of existing plans for expansion, the University will require a total of 183 graduates in pure science and mathematics and 84 in applied science, representing an annual intake of 37 and 17 respectively. To make up for loss due to retirements, a further recruitment of about 15 graduates will be required per annum, making a total demand for the University of about 70 graduates per annum in science and mathematics. It must be emphasised that these graduates will be drawn from the category with high honours degrees and the requirement of 70 graduates represents nearly one-fifth of the total average output of honours graduates of all classes for the years 1958–61 (Table 11.2). The proportion of the number of first class honours graduates to the total number of honours graduates is generally less than about one-fifth, so that it is clear that the University itself will on the average require a high proportion of its best graduates, including practically all its annual production of first class honours graduates if only to maintain itself, during the period of expansion already planned. In the case of mathematics it is shown in Chapter XI that, as far as numbers are concerned if Wales is regarded as a viable unit (see Chapter I), the University itself would need to absorb almost all its first class honours graduates, leaving none to meet other demands from industry and the schools for such graduates.

To implement the recommendations of the recent Report on Higher Education, a further degree of expansion is envisaged, even within the present quinquennium, and still further increases are planned for the 1967–72 quinquennium. In these circumstances, it is not unrealistic to expect the University to require about 80–90 graduates per annum over the next decade.

14.3 Training Colleges

The current plan for the expansion of the number of places in training colleges is such that by 1966 there will be about 3,000 students in the eight general training colleges in Wales, most of them following a three year course. This number will require about 380 members of staff, of whom about 70 will be in science and mathematics (see Chapter IX). The increase in the number of graduates required over the five years from 1961 is estimated as 39; this, together with normal replacement due to retirement, requires, as a conservative estimate, an intake of about 10 graduates a year. There are, however, other factors to be considered which are likely to increase this estimate.

Current policy dictates that 80–85 per cent of students in training colleges will enter primary schools, and the remainder will enter secondary schools. Most of the latter will, in fact, become qualified as specialist teachers of such subjects as handicrafts and physical education, and only a few will qualify as teachers of mathematics and science. Thus it follows that only a very small contribution will be made to the supply of teachers of mathematics and science for secondary schools. Further, only a very small proportion of teachers enter primary schools with qualifications in physical science at Main Course level.

Table 14.1 *Distribution of Students in selected Subjects at Main Course Level;* 1961–62

Subject	Number of Students	Percentage of Total
Mathematics	69	7·1
Physical Science	7	0·7
Biological Science	78	8·1
History	101	10·4
Geography	140	14·4

Table 14.1 shows that the number of students taking physical science is very small compared with the numbers taking other subjects. If this picture is to be improved then more lecturers qualified to teach the physical sciences will be required. Further, if the training colleges are also to make a greater contribution to the supply of secondary teachers to teach more science in secondary schools as discussed in Chapter V, then a substantial increase in the number of training college staff qualified in science and mathematics will be necessary.

There is already a clear indication of difficulty in recruiting lecturers in these fields; only a third of the mathematics staff for instance have high honours degrees (Chapter IX, § 5) and in the future the position is not likely to become easier in the face of the University demands commented on in Chapter XI.

It is suggested that the above considerations point to the need of doubling the annual intake of 10 graduates referred to in the first paragraph. It is, however, also necessary to allow for the further expansion in training colleges which is already being planned for the years following 1966; and taking all these factors into consideration an annual intake of 25 to 40 graduates in science and mathematics would seem to be necessary over the next 10 years, to meet the staffing needs of the training colleges in Wales. If the Report on Higher Education is implemented the demand for staff will be even greater.

14.4 Technical Colleges

Table 10.2 in Chapter X shows that the expansion which has already taken place in the technical colleges is expected to continue. The figures in this table are based on the existing schemes of work and take no account of any changes that may take place in the pattern of higher education. It is estimated in Chapter X § 6 that to meet this expansion an annual intake of about 80 graduates in mathematics and science, including applied science, and about 10 with professional qualifications of graduate standard, will be required. There are, however, a number of factors in connection with the future of technical college work which may make it necessary to increase this rate of recruitment very considerably. These, briefly, are as follows: the introduction of compulsory day release for young people in industry up to 18 years of age; the lengthening of the technical college year to 44 weeks; the replacement of part-time day courses by block release courses for craft apprentices; the more extensive use of full-time and sandwich courses for students who now follow part-time day National Certificate courses; and, following the introduction of the Industrial Training Bill, a greater involvement of the technical colleges in the industrial training of young workers, particularly in their first year or two.

Even the partial introduction of any of these changes would make necessary substantial increases in the number of staff in the technical colleges, some of whom would be required to be qualified in mathematics and science. The figure of 80 to 90 science and mathematics graduates a year required for the technical colleges must therefore be regarded as a minimum requirement.

14.5 Schools

14.5.1 *The Problem*

Any attempt to assess the needs of the schools must take account not only of factors associated with increased numbers of pupils, but also of the very serious deficiencies in the qualifications of existing teachers of mathematics and science in secondary schools discussed earlier in Chapter VII.

In assessing the staffing needs of all secondary schools it is convenient to deal with modern schools and grammar schools separately, since the necessary qualifications of teachers of mathematics and science are not the same in the two types of school. In the case of bilateral and comprehensive schools it has been assumed that one-third of their pupils follow a 'grammar' type course and this has been taken into account in our estimates.

14.5.2 *Secondary Modern Schools*

There were in 1962 about 110,000 pupils following 'modern' courses (Chapter V § 1) requiring about 4,930 members of staff, on the basis of a pupil-staff ratio of 22.3 to 1. Information received from the schools showed that, on the average for all schools, 22 per cent of the total time available each week was devoted to mathematics and science. The schools thus required 1,085 teachers of these subjects. If it is accepted that the minimum requirement for teaching in a secondary modern school is the study of a subject to the level of a third year training college course, or the possession of an appropriate university degree, then the information received from the schools shows that only 200 teachers possess such qualifications. This number is made up of 64 in mathematics, 33 in physical science and 103 in other branches of science. Assuming that the position is similar in the other schools where 'modern' pupils are taught, we obtain a total of only 250 teachers thus qualified against a need in 1962 of 1,085. On this view then there was a deficiency of about 835 appropriately qualified teachers of science and mathematics in secondary modern schools.

The position is in fact more serious than this, because very many schools devote a total of only two or three periods a week to science subjects, owing largely to inability to recruit suitable staff. If science, which is a practical subject, is to make its proper contribution to a balanced education, and if pupils are to study science satisfactorily to the level of the new C.S.E., the amount of time now being devoted in many schools to science must be doubled. This in turn will require something like a further 400 teachers of science. We have previously emphasised the importance of small classes for teaching science and we considered that groups of about 20 pupils were large enough for practical work, This would involve halving the size of existing classes in many schools, particularly in urban areas, and would require something approaching 200 additional teachers.

The present tendency to stay on in school after 15 years of age and the ultimate raising of the school leaving age to 16 may well require a further 20 per cent increase in staff of secondary modern schools. In fact the increase could well be greater than 20 per cent if more time is devoted to science and mathematics in courses with a vocational bias. An estimate of this requirement is 200 teachers.

Ignoring such factors as the age distribution of the teachers, which for the better qualified teachers is weighted in the direction of the higher age group, the secondary modern schools require 835 teachers with appropriate qualifications in science and mathematics if all the pupils there are to be taught in science and mathematics by teachers with minimum qualifications in those subjects. To ensure the improved teaching of mathematics on the lines discussed above, and which we regard as necessary, a further 800 teachers would be required. To achieve this within five years an annual recruitment of 320–330 will be necessary; if within a period of 10 years the annual recruitment rate is of course halved. To this must be added the annual intake necessary to compensate for retirements, promotions and other losses. On the basis of an average teaching life of 30 years such replacement would require about 35 additional teachers at the 1962 level of staffing. Moreover, if the recommended improvements in the teaching of science are to be implemented, this involves a replacement figure of 70 a year.

To sum up, if we envisage a ten-year period in which to bring the schools up to the standards recommended, including the raising of the school leaving age, then an annual recruitment of about 230 teachers appropriately qualified in mathematics and science will be required. Of these, 70 will be required for replacement, 80 to remedy existing deficiencies and 80 to effect recommended changes.

14.5.3 *Grammar Schools*

The 68,500 pupils who in 1962 received a 'grammar' type education required 3,425 members of staff on the basis of a pupil-staff ratio of 20 to 1. Section 2 of Chapter VII shows that about 30 per cent of teaching staff are engaged in the teaching of science and mathematics. This required 1,028 teachers, and an average annual recruitment of about 30 new teachers to maintain present strength. It must be noted, however, that the age distribution of better qualified teachers is weighted towards the higher age group and the annual intake over the next 10 years needs to be greater than the average annual recruitment.

It is shown in Table 1 of Appendix II that about 187 graduates, of whom about 106 should be graduates in mathematics, are required to remedy deficiencies due to the employment of inadequately qualified teachers. Rectification of this position within ten years will require about 20 graduates a year, making the total requirement of the grammar schools about 50 graduates a year, of whom 30 will be for replacement and 20 for improvement of the teaching of science and mathematics.

14.6 Summary

An estimate was made of the total annual requirements of the full educational system of schools, colleges and University in Wales for teachers with appropriate qualifications in mathematics and science. The universities will normally require those with the highest honours, and indeed similar requirements apply to all those undertaking advanced work in other institutions of higher education. Further, teaching in the sixth form of grammar schools involving work of G.C.E. Advanced and Scholarship level standard also requires graduates of high academic standard. Thus we find that there will be an annual requirement of from 215 to 240 graduates, the majority of whom should be with high honours.

If the policy of providing graduates for teaching mathematics and science in modern schools is to be implemented, this will mean a further annual requirement of about 230 graduates. Assuming that these had only pass degrees we arrive at a total requirement of about 445 to 470 graduates annually, of whom about one-half should have honours degrees.

In a previous chapter we considered the numbers of graduates in pure and applied science and technology required for industrial, central and local government laboratories and offices. In this chapter we have estimated the numbers of graduates in mathematics and the pure sciences required for the teaching profession, as graduates in the applied sciences or technology do not usually become teachers in secondary schools. The largest number of graduates is required in mathematics, then comes physics and chemistry in that order. In the next chapter we shall consider whether the numbers graduating in mathematics and science from the University are likely to be sufficient to meet these estimated demands.

Chapter XV

SUPPLY AND DEMAND

The purpose of this chapter is to discuss the supply and demand of graduates in science and mathematics in order to consider whether the present serious deficiencies in the staffing of secondary schools are likely to be remedied in the foreseeable future. We regard the present insufficient supply of graduates, particularly of those with good honours degrees, as one of the most serious problems facing the schools.

We have, in Chapter XI, considered the estimated annual output of mathematics and science graduates from the University of Wales and, in Chapters XIII and XIV, made an estimate of the annual demand for graduates from industry and the educational system. It is now necessary to consider the total demand and compare it with the supply of graduates from the University.

In general, graduates in the applied sciences and technology proceed straight to industry and not to the teaching profession, except for a number who take up posts in technical colleges. The demand in schools is mainly for teachers of mathematics and pure science. On account of the special demands (for example, from research establishments and universities) for those with high qualifications it is also necessary to consider separately the supply of graduates with honours degrees.

It has been shown in Chapter XI that the total output of honours graduates in mathematics and pure science was 252 in 1961–62 and this output is expected to rise to 500 in 1966–67. The output of applied scientists with honours degrees was 137 in 1961–62, and this also may be expected to double by 1966–67. (Table 11.2). There were also 298 pass graduates in 1961–62 and this is also expected to double by 1966–67. It will be noted that the combined total of pass and honours graduates in 1961–62 was 687.

The total average annual requirement of industry is very difficult to estimate but in Chapter XIII it is suggested that a conservative estimate is about 350. In Chapter XIV it is shown that the total demand of the educational system in Wales, including schools, colleges and University, is for about 445 to 470 graduates in science and mathematics each year. The combined total demand is thus about 800. It must be noted however that this figure is based on the assumption that many of the existing deficiencies in school staffing will be corrected, and many of the recommended reforms implemented, over a period of ten years. To achieve these aims in a shorter time, say five years, would increase this figure by about 250. There may also be changes in the industrial pattern such as the establishment of more units of 'science-based industry' which could also affect the figure by increasing the demand. Implementation of the Report on Higher Education (1963) will certainly increase the demand of institutions of higher education for the more highly qualified graduates.

This total demand may be compared with the output of science and mathematics graduates from the University of Wales which is expected to rise from 687 in 1961–62 to about 1,400 in 1966–67, giving an average annual output over the five year period of just over a thousand.

On the face of it university institutions in Wales appear, with their programme of expansion, to be in a position to meet the overall demand for graduates in Wales. This conclusion is made in accordance with our constant assumption that there will be a state of equilibrium in which the number of Welsh graduates seeking employment elsewhere can be equated with the number of graduates of other universities who find employment in Wales; that is, for this purpose, Wales is considered as a viable unit, It may also be noted that the number of university places in Wales is, per head of population, greater than the average for the United Kingdom. However, the overall figures give no indication of the particular needs of various types of institution within the system. In general, applied science graduates proceed to industry and the demands of the higher education establishments and research organisations are for people with the highest academic qualifications.

The total demand from institutions of higher education is about 190 graduates per annum and these would be expected to be the most highly qualified honours graduates. The total output of honours graduates in mathematics and pure science is expected to rise from 250 to 500 in the five year period from 1961–62, representing an annual average of 375. The proportion of those with first class honours is likely to lie between 10 and 20 per cent, so that the number of such graduates is unlikely to be more than about 75 each year. Industry in Wales is also seeking to recruit first class honours graduates and, if its share of this category is not more than 10 per cent of its total intake of 350 graduates, this demand alone will take up 35 first class honours graduates, although this figure may well be higher. Some account must also be taken of the (in fact, most effective) demand from large industrial and research establishments in the rest of the United Kingdom and other parts of the world, particularly in the United States of America, which is at present successfully attracting many good graduates. Thus the total demand of 225 highly qualified graduates (190 for higher education and 35 for industry) cannot be met from the estimated output of 75 first class honours graduates. It is assumed in making this estimate that the proportion of first class honours graduates will remain at about 10 to 20 per cent of the total during the period of university expansion when an increasing proportion of the age group will enter on degree courses. If, in fact, the proportion falls, then the situation will obviously become worse.

Clearly, this demand for high honours graduates can only be met by employing graduates other than those with first class honours. Experience has shown that the proportion of firsts and upper seconds taken together is seldom more than half the total. However, even this total output (half of 375, that is about 190) does not meet the expected demand of 225 referred to above.

It is clear that since World War II, industry, government research establishments and institutions of higher education have all shown themselves to be in more favourable positions than the grammar schools when competing to recruit the honours graduate. It seems clear that under present conditions the grammar schools have only a remote chance of obtaining a fair share of the best qualified graduates in science and mathematics. Further, as we have seen in Chapter XI, the general academic level of the annual entry of these graduates to the University departments of education has been falling and, in view of the magnitude of the other demands described above, there seems no great prospect of the situation changing markedly for the better in the immediate future.

Thus it follows that, over the next five to ten years, the vast majority of the teachers available to our grammar schools for mathematics and science will of necessity be pass graduates. This is bound to have a serious effect on the whole character of, for example, sixth form work. This conclusion might itself also be unduly optimistic, as it assumes that all those graduates in mathematics and science who are not recruited to professional (scientific or mathematical) posts in industrial laboratories or higher education will then elect to enter the teaching profession. Like many of today's arts graduates, these science graduates may well prefer to take up other posts (for example, administrative or executive) which are not professionally scientific or technical.

PART IV
GENERAL ASSESSMENT AND CONCLUSIONS

Chapter XVI

ASSESSMENT

16.1 A Balanced Education in the Schools

16.1.1 *Aims and Trends*

In our Report we have considered the place of mathematics and science in a balanced system of education in Wales. In its nature and organisation this system is, of course, substantially the same as that in England. However, we have, throughout, been aware that our system differs in many important respects from that obtaining in other countries and we believed it would be of general interest to note some of the features which indicate a different approach. These are summarised in Appendix VII.

As we have noted earlier, the educational system is part of the general social scene and as such reflects the needs and trends of that society. What has been described as the second industrial revolution is having its impact on modern society and the educational system is now recognising the new challenge, as far as numbers of scientists and technologists are concerned. The drive for increased numbers has, however, been characterised by a high degree of specialisation; the age has seen the emergence of the technical expert and the professional, and our traditional intellectual disciplines in arts and science have increasingly been fitted into separate compartments. However, there are welcome signs now of a realisation that a change is necessary, and that the need for the re-integration of learning is pressing. Society in general and industry in particular are moving beyond the limited objective of more scientists and technicians with a highly specialised but narrow educational background. There is a need for an intellectual environment in which we think of the different academic subjects, not as separate entities, but as branches which have sprung from (and all draw their life from) a common core of knowledge and ideas. As we pointed out in Chapter III, modern society should demand an educational programme which aims at giving all persons not only a training in particular specialisms, but also a basic general knowledge of major human activities and an awareness of man's powers and responsibilities in a changing society.

In a modern industrial society excessive specialisation in school and college can defeat, and is defeating, its own purpose. When they enter industry, people trained in this way may be effective initially but their lack of adaptability and breadth will seriously hinder not only their own advancement but the progress of the industry itself. With the technical transformations likely in industry in the not-too-distant future, and the increased use of automation, the opportunities for the school leaver who is lacking in this adaptability and breadth will be much more limited. The consequent increase in leisure time will also present a formidable problem for those ill-fitted to make the best use of it.

We have already noted that the Welsh educational system has a tradition of balanced studies covering the arts and sciences. The schools established after the Welsh Intermediate Education Act of 1889, in general, recognised that science should be an important part of the curriculum. The constituent Colleges of the University of Wales have, from their foundation, developed scientific studies along with the humanities. Furthermore, it is well to remember that these studies were offered to everyone who had the necessary ability; they were not restricted to any particular social class or section of the community. Thus, as far as its original aims and early growth were concerned, the Welsh educational system realised the importance of a balanced education and, in the main, provided this.

However, from our inquiry into the degree of balance afforded by present studies in the secondary schools of Wales we have concluded that the position today cannot be regarded as satisfactory. Our detailed observations on current trends have been given earlier; we here give broad conclusions. It is clear that there is excessive specialisation in the grammar schools today. This tends to start as early as the third year, sets the pattern for work in the fifth form and, to a large extent, influences the choice of subjects in the sixth form.

We are firmly convinced that courses up to and including the fifth form should be broadly based on the lines we have previously discussed. However, the large number of subjects frequently taken by individual pupils in the fifth form often results in superficial treatment; the majority of pupils need more time for a concentrated study of subjects in both arts and science which we would consider basic at this stage.

In the sixth form, with its increased numbers, the pressures of university entrance requirements are such that a broadly based education is being sacrificed to the demands of specialised courses.

Premature specialisation leads to the danger of confining a pupil's choice of subjects up to and through his degree course. A student can find it difficult, or consider it inadvisable, to pursue subjects at the university which are different from those he has taken in the sixth form and in which he presumably considers himself 'well trained'. In many cases it would be preferable if pupils in the sixth form were permitted to take a combination of three Advanced level subjects which would include one subject selected from the 'other' side (for example; mathematics, French and German, or mathematics, physics and English). In this respect the universities exercise a determining influence and could be of considerable help in broadening sixth form courses; and we can think of no single factor that would have such a beneficial influence as the recognition in practice by the universities of the combination of arts and science subjects at the Advanced level.

16.1.2 *The Effect of the Shortage of Teachers*

Quite apart from any organisation involving excessive specialisation, there is another factor which is seriously affecting the provision of a balanced programme of studies in the schools. This is the difficulty facing the schools in recruiting suitably qualified teachers, particularly in mathematics and science. This applies as much to the primary schools as to the sixth forms of grammar schools. This very important matter is considered more fully later in this chapter.

16.1.3 *The School as a Good Society*

Throughout we have emphasised our view that there is need of a liberal construction of what constitutes worthwhile courses of study. These in turn will be forthcoming only if the personal qualities of teachers and pupils alike are of a kind to ensure fulfilment of the aims envisaged. The underlying assumption is that a good school is a 'good society', both in its own right and as one which points the way to desirable advances in the wider society of which it forms a significant part.

We are aware that the values which are current in the good school are unlikely to be acceptable to many among whom the pupils, when they have left school, will spend their hours of work and leisure. There is evidence that even at home they may be subjected to influences which, in effect, if not in intention, may serve to undermine the efforts of the schools to encourage high standards of conduct and self-discipline.

There are moreover signs of a growing sensitivity in various quarters to a possible danger of advantage being taken of inexperience and immaturity, through teachers seeking to propagate their own views on moral issues among their pupils. However, we should be most reluctant to favour any safeguard which would impress on the teacher the need of maintaining a cold attitude of neutrality on aspects of living which are of deep practical concern to the young people for whose welfare he is today, perhaps more than ever before, largely responsible.

We respect the sincere desire of a teacher to avoid any misuse of his power to influence his pupils; we would add that it is unlikely that a man so alive to his responsibilities could fail to exercise a beneficial influence upon them. But we are concerned about the contrast of attitude that his pupils are likely to encounter among those with whom they will have to do when they leave school. For these will include many who have little interest in their welfare and some who are prepared to exploit their inexperience. It is for this reason that we view with alarm any prospect now or in the future of the teacher's traditional duty of 'influencing his pupil for good' being construed as propaganda. There is an aspect of the problem which is of special concern to us if we are to take a comprehensive view of the place of science in modern education. While we regard it as a high merit in a teacher of science if he succeeds in encouraging in his pupils an open-mindedness and a refusal at all times to follow except where the evidence lights the way, we nevertheless recognise that there are fields of human effort and decision in which scientific procedure may offer little direct guidance. In current discussions of religion and of moral problems we feel some uneasiness regarding the confidence with which such antitheses as pre-scientific and scientific, and objective and religious, are on occasion so sharply drawn. In brief, we are of the opinion that it is the scientist who, *qua* scientist, is most keenly aware of both the possibilities and the limitations of his activities.

We cannot fail to note the adverse effect that the decline of the Christian religion in this country has had in fact, if not inevitably in principle, on the efforts of teachers and others to provide that *support* for the successful conduct of life which has been regarded in this country as an essential part of the teacher's contribution and the child's birthright. We would strongly endorse the view expressed in the first report of the Central Advisory Council for Education (England).*

The problem was clearly posed some centuries before the beginning of our era: 'When concerning the way in which gods and men honour virtue and vice, we find statements such as these made repeatedly and in the same tenor, what can we think will be their effect on the souls of those who hear them, young men of good natural dispositions who, like bees, fly from one statement to another, gathering from them all an answer to the question: What must a man be, and what paths must he take, if he would live the best possible life?'*

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* *School and Life*, Chapter VII 'The Moral Factor'—A Report of the Central Advisory Council (England), 1947.

It seems best to let these words speak for themselves, and to suggest that the teacher's most effective contribution towards helping his pupils to determine their answer to the question is that of his personal example. Children, like scientists, draw their conclusions from the evidence presented to them, and theory that conflicts with experience is soon discarded.

16.2 The Present Crisis in the Supply of Teachers

Mathematics and science, taught in an enlightened and imaginative way, can make a substantial contribution to a liberal education. As in all subjects, the effectiveness of the contribution depends upon the enthusiasm and background of the individual teacher. As a result of our inquiries, however, it is very clear that the teaching of mathematics and science is rapidly declining in quality. There are too few teachers with suitable qualifications in these subjects entering the schools and it is likely that there will be fewer in the foreseeable future.

It is our considered view that this matter is so serious as to imperil the whole structure of science education in this country unless steps are taken, with the minimum of delay, to alleviate the present shortage and at the same time to increase the rate of recruitment of mathematics and science teachers. The magnitude of the crisis justifies and demands action which can be taken only by the Government.

The present demand for mathematicians and scientists by industry, government and other research establishments is curtailing recruitment to the schools to such an extent that the future supply of qualified people is likely to be cut off at its source. Our surveys of the position in the schools have revealed that they are at present existing very largely on their 'scientific teaching capital' as far as staffing is concerned. For instance, when we considered the age distribution of the more highly qualified teachers—those with honours degrees of all classes—we found that in general the most highly qualified were in the category of oldest teachers. When this group retires within the next few years, those teachers who will replace them will have much lower academic qualifications. This indicates how the 'scientific teaching capital' in the schools is being exhausted. Because of the lee-way to be made up, the shortage is likely to remain for some years, even if the rate of recruitment rises.

As the quality of those recruited as teachers of mathematics and science continues to deteriorate, the better qualified teachers still in the schools are having to confine their teaching to the fifth and sixth forms. It is a serious disadvantage that these teachers are not able to have an impact on pupils in the lower and middle school. Children are naturally influenced by the most stimulating teachers and many able pupils may well lose any initial interest they might have had in science. In general, the able pupil will tend to follow the able teacher, whatever the subject. The cumulative effects of the teacher shortage can jeopardise the basis of science education in the secondary schools and therefore the development of higher education as well.

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* *The Republic of Plato*, translated by A. D. Lindsay (London: Dent) 1908.

We appreciate that it is necessary for modern science-based industry to be able to recruit its fair proportion of highly-qualified scientists and technologists in order to maintain and develop its administrative, technical and research activities. Equally, institutions of higher education require similarly qualified scientists both to maintain themselves and in order to provide for planned expansion.

Industry, the government, institutions of higher education and the schools are all seeking to employ the well-qualified scientist and mathematician. In general, the attractions of the modern research laboratory are such that the schools are now unable to compete with these others in recruitment. The ultimate source of potential scientists and mathematicians is the schools and this must at all costs be safeguarded. If this trend continues—and at present it seems unlikely that the position will change—then clearly the source of potential mathematicians and scientists with the necessary educational background will diminish and could even dry up. A policy by which the most highly-qualified, potential scientists are diverted from the schools (to government or industrial research) must eventually cut off the supply of mathematicians and scientists for those establishments.

At present, there is little evidence to show that the proposed expansion of the universities will result in a corresponding increase in the number of highly-qualified graduates (such as those with first class degrees), since the indications are that the proportion of these to the total number of graduates is tending to fall. The continuance—let alone any development—of science education in this country can be assured only if the schools are able to recruit their fair proportion of well-qualified graduates in mathematics and science.

It is our considered view that this is essentially a matter of priorities in the country as a whole and we would make the strongest possible recommendation that the absolute importance of having a sufficient number of well-qualified teachers working in acceptable conditions in the schools should be urgently and generally realised.

16.3 Some Suggestions for Meeting the Demands for Teachers of Mathematics and Science

We have seen that the usual sources will not satisfy the present demand for well-qualified teachers of mathematics and science. Consequently it is necessary, firstly, to consider other sources from which they may be recruited; secondly, the possibility of deploying more fully those good teachers who are in the schools; and, thirdly, to consider methods whereby those who are less well-qualified may be helped to become more successful teachers of these subjects. In view of the existing competition, it is vital also to strengthen the claims of the teaching profession by making conditions of service more attractive to the young scientist.

While realising that this is a matter of national priorities, nevertheless we bring forward suggestions for improving the position, and these we give below under two broad headings. Many of these have arisen from our analysis of the evidence, both written and oral, which we have received. Some are palliative measures only, while others, we believe, are of more permanent significance.

16.3.1 *Conditions of Work and Sources of Recruitment*

We are led to conclude that more well-qualified graduates would be attracted to the teaching profession if their working conditions in the schools were generally improved. Of particular importance is the provision of well-equipped and serviced laboratories, together with adequate technical assistance. Economies in these fields could militate against improving science education.

We would advocate closer links between the schools and institutions of higher education, with opportunities for teachers to follow advanced courses and to do postgraduate research work, leading perhaps to higher degrees. We would here refer to the work of the Scientific Research in Schools Committee of the Royal Society. Its terms of reference are to assist school science masters and mistresses who wish to pursue research.

There are in the country considerable numbers of married women with academic qualifications in science and mathematics. We believe that more would be prepared either to return to the schools or to enter the teaching profession if this were made easier and more attractive for them. In particular, there should be more opportunities for them to do part-time work in schools near their homes.

The additional university year required to complete a course of training in a university training department still presents difficulties. We have received evidence that very often students who have decided on a teaching career are anxious to start immediately after graduating, and this is particularly true of those who are not in receipt of full grant; these students feel that they cannot ask their parents to make a financial contribution for another year. The grants for this training year are, at present, among the very few grants for postgraduate courses which are subject to a means test. We consider that there is a strong case for a revision of the existing grants system applicable to the course of training in a university training department.

Since the universities, even with the planned expansion, will be unable to meet the demand for well-qualified teachers of mathematics and science in the secondary schools, it is clear that many more of such teachers will be needed from the training colleges. As we pointed out in Chapter IX, in the training colleges in Wales the total number of 46 places at present allocated for students to be trained as teachers of science and mathematics in secondary schools is wholly inadequate.

Many pupils who obtain only one pass at the Advanced level in a science subject and thus do not possess the necessary qualifications for entry to a university now embark on a Higher National Diploma course at various colleges of technology. These courses are of three years' duration, the students attending at the college for two terms each year and spending the other term and most of the summer vacation in industry. Some of these students have, after obtaining their Diploma, attended a technical teacher training college for one year and have become useful teachers in institutions of further education, and a number would be suitable for teaching in secondary schools. There is no technical teacher training course in Wales. We recommend that the possibility of establishing such a course in Wales be explored as a possible new source of teachers of mathematics and science in the schools.

In Chapter VIII we drew attention to the substantial number of pupils—about 1,700 a year—in the sixth forms of secondary schools in Wales who are being lost to full-time higher education. Many of these, given the opportunity, might well make effective teachers of science and mathematics in secondary modern schools. We have noted earlier that only two per cent of school leavers with two Advanced level passes in science subjects now enter training colleges in Wales.

16.3.2 *Teaching Aids and In-service Training*

From evidence we have received it is clear that teachers are particularly anxious to experiment with new materials and with new media of instruction. Many have been impressed by television programmes in science and mathematics, and we would urge that study should be made of the use of television in this work in the schools. The potential of this, and other audio-visual aids, is still little realised and research into their value and use should be expedited.

Consideration should be given to experimental work with closed-circuit television in the bigger schools. Where classes in science and mathematics are large, this might be a method of extending the effective teaching of one person to a larger number of pupils within the school.

In 1962 the Nuffield Foundation set aside £250,000 towards the cost of a comprehensive long-term programme to improve the teaching of science and mathematics in schools. We welcome this venture and believe it should have every support. With the shortage of well-qualified teachers in these subjects, the projects will fulfil a long-felt need in the schools and we hope that some schools in Wales will be associated with the experimental work.

Programmed learning and teaching machines have aroused considerable interest. Most of the experimental work in this field has been done in the United States and useful, but by no means conclusive, results have been obtained. It is clear that programmed learning, although still in its infancy has a considerable potential and we welcome, therefore, the research work which is now being done on it in various parts of the country.

Courses for practising teachers of mathematics and science at present in the schools are a prime necessity. Short courses of a few days' duration can achieve little; nothing less than a co-ordinated, sustained effort will suffice. We would urge also that teachers should be able to attend such courses with no financial loss to themselves.

Consideration should be given to the establishment of a Diploma in Science parallel to the Diploma in Mathematics of the Mathematical Association. This would give qualified teachers special help to fit them to be good teachers of science in the secondary modern schools and the lower forms of the grammar schools. More teachers would be encouraged to work for these Diplomas, if all local education authorities granted day release to members of staff in their schools.

Chapter XVII

CONCLUSIONS AND RECOMMENDATIONS

We list here the detailed conclusions and recommendations to which we have been led as a result of the considerations of the previous chapters. It is important that these should be read in conjunction with the full discussion and to enable this to be done a reference is made to the relevant chapter and section in the Report. We would stress that some of these conclusions refer to matters which over-ride in importance all the others; accordingly, these are our first five conclusions.

STAFFING

1. The present shortage of highly, or even barely adequately, qualified teachers in mathematics and science, together with the progressive decline in the standard of recruitment, is the most serious problem affecting the teaching of these subjects in the schools of Wales . . . (7.1.sq.).
2. This problem is not confined to Wales; it is, in fact, of world-wide extent. As far as Wales is concerned, however, we consider that the seriousness of the situation has not been adequately realised. It is becoming difficult, and may soon become impossible, to maintain a standard of teaching in mathematics and science even at its current level. Unless this trend is halted soon, the deterioration in the situation will jeopardise the basis of science education in the schools, and consequently the supply of scientists necessary to meet the scientific, educational, industrial and social needs of the nation. This clearly has the gravest implications for any programme of expansion of institutions of higher learning within the next decade . . . (7.2; XIV).
3. We regard it as a matter of the greatest urgency that all steps should be taken at a national level to provide teachers qualified to give the kind of education in science and mathematics which is appropriate to this age of rapid scientific and technological advance . . . (7.3; 16.2).
4. It is to be deplored that, owing to this shortage, there is a widespread practice of offering important permanent posts in secondary schools to inadequately qualified applicants. This practice will prevent the proper deployment of better qualified teachers, if and when they become available . . . (7.2).
5. Another consequence of the present shortage is that classes, both in primary and secondary schools, are still too large, and there is an urgent need to reduce their size. This, however, can only be achieved with a great improvement in the supply and quality of teachers . . . (IV, V, VI).

LIBERAL EDUCATION IN THE AGE OF SCIENCE AND TECHNOLOGY

6. There is a contemporary need for a synthesis of arts and science which will enable the individual to play a responsible part in a modern democratic society. Education should be along broad lines, including arts, mathematics

and science, for as long a period as is reasonably consistent with an individual's ability and aptitude. Early specialisation should be avoided . . . (3.2; 3.4).

7. Vocational training, when it becomes necessary, should always be supplemented by wider non-vocational studies . . . (3.4).

8. If the trend of Welsh society to split into two parts, the one industrial and anglicised and the other rural and Welsh, is to be halted, the Welsh language must play its full part in scientific studies. We recommend that, in Welsh-speaking areas, greater use should be made of Welsh as a medium of instruction in both mathematics and science . . . (3.3.2; 3.5).

THE EDUCATIONAL SYSTEM

Primary Schools (Chapter IV)

9. The broad base of a liberal education must be laid in the primary school, but there is a scarcity of teachers with mathematical and scientific background . . . (4.1).

10. Much of the work in mathematics is still over-computational in character. Children at this stage need a broader mathematical experience . . . (4.2).

11. Science, as a specific subject involving an organised body of knowledge of natural phenomena, has no place in the primary school. We believe that it should be brought in as an integral part of the child's environmental studies. The emphasis should be on curiosity and a sense of wonder . . . (4.3).

12. The pressures exerted by the kind of attainment tests in current use at the 11 plus stage have a detrimental effect on the breadth and balance of work, and the all-round development of the pupils, in the majority of junior schools . . . (4.4).

Secondary Schools (Chapter V)

13. We believe that a minimum basic curriculum for pupils in all types of secondary schools should include Language and Literature, History and Geography, Science, Mathematics, at least one of the Arts, Physical Education and Religious Instruction. In Wales the linguistic position is such that due place must be given to both Welsh and English . . . (5.2).

Mathematics

14. We consider that the over-riding aim in the teaching of mathematics at this stage should be to cover a range of subjects not limited to arithmetic and purely vocational needs. The teaching of mathematics in many secondary schools would be more effective if, in addition to the acquisition of skill in techniques, the emphasis were laid on the relative understanding of underlying principles and relationships based on experience . . . (5.3).

15. There should be greater continuity of method and content between the mathematics teaching in the junior and in the secondary school. In the later years in the secondary modern school, mathematics should be studied in conjunction with vocational interests, thus linking with colleges of further education . . . (5.3).

16. We regret the tendency to regard technical drawing as a separate subject, often divorced both from mathematics and handicraft, and we recommend that it should be taught in its proper context, and so be integrated with the

mathematics syllabus in the early years and with handicraft in the later years . . . (5.3).

17. Modification in the content and treatment of mathematics in secondary schools is highly desirable. We would encourage, therefore, the conduct of experiments in individual schools . . . (5.3).

18. There is a strong case in Wales, with its relatively high grammar school intake, for a mathematics course which would trifurcate after two or three years to provide for (a) the abler pupil who could cover the Ordinary level and the Additional Mathematics courses in five years, (b) the majority for whom the Ordinary level course is suitable, and (c) the less able who now give up mathematics for arithmetic only . . . (5.3).

19. It is disappointing to find that only the small proportion of five per cent of all those taking mathematics at the Ordinary level are entered for the Additional Mathematics examination . . . (5.3).

20. We recommend that the Special Examination in Arithmetic should be discontinued and that the substantial number of pupils who now confine themselves to arithmetic only should follow a course in mathematics devised at a level which is commensurate with their ability in the subject . . . (5.3).

Science

21. In many secondary modern schools where only two or three periods a week are devoted to science there is need for a more generous time allocation . . . (5.4).

22. The traditional pattern of choice involving biology for girls and physical science for boys is still too common, especially in secondary modern schools . . . (5.4).

23. The factual content of the syllabuses needs to be reduced . . . (5.4).

24. Practical science classes should be limited to a maximum of about 20 pupils as soon as staffing permits . . . (5.4).

25. Few pupils can afford to give more than 10 periods a week (out of 35) to science subjects without harming their general education. The majority of pupils should take not more than two science subjects in preparation for the Ordinary level examination . . . (5.4).

26. Neither General Science nor Additional General Science in their present form is considered to be a good preparation for Advanced level work in science in the sixth form . . . (5.4).

27. We deplore the proliferation of science subjects known as, for example, Engineering Science, Horticultural Science, Human Biology, Agricultural Science which can now be taken at the Ordinary level. We believe it is to the advantage of pupils to concentrate at this stage on the fundamental sciences of physics, chemistry and biology. Alternative syllabuses within the framework of these basic subjects might well be considered . . . (5.4).

The Sixth Form (Chapter VI)

28. Non-specialist studies in the sixth form are not at present making an adequate contribution to the general education of the pupils. We recommend that the time allowance for specialist subjects, including practical work and private study, should be not more than about two-thirds of the total teaching time . . . (6.1).

29. A better balanced curriculum can be generally achieved only through a lightening of syllabuses, improvements in staffing and a better understanding between the schools and universities of each other's needs and problems . . . (6.1).

30. Variety, individuality and freedom to experiment are the very essence of minority time work and we would, therefore, oppose any proposal to examine such work externally . . . (6.1).

31. The combined Pure and Applied Mathematics paper is academically weak and should be discontinued . . . (6.2).

32. We recommend that mathematics in the sixth form should be studied and examined as one single subject, which should consist of Pure Mathematics . . . (6.2).

33. The proportion of girls in girls' schools taking science is higher than in mixed schools . . . (6.3).

34. There is a tendency to underestimate the importance of a mathematical background in science courses other than physics in the sixth form. We recommend that all pupils taking a science subject, but not mathematics, at the Advanced level should follow a course of mathematics such as the Ordinary level course in Additional Mathematics . . . (6.3).

35. There is evidence to indicate that the separate subjects of Botany and Zoology have outlived their usefulness in the school curriculum and might be replaced by the single subject, Biology, with a suitably revised syllabus . . . (6.3).

36. The diversity of university entrance requirements as they affect individual subjects and the restrictions imposed by some universities and faculties as against others cause difficulties in the schools. More flexibility in faculty requirements would be to the mutual advantage of the schools and the universities and could contribute to a broader education. For instance, there may be advantages in a sixth form pupil choosing his three Advanced level subjects from both arts and science. Too few pupils take a science and arts combination . . . (6.4; 16.1.1).

37. We are concerned that so little has been achieved in the revision and reduction of syllabuses. If the existing subject panel system of the Examining Bodies is ineffective in bringing this about, we would urge that some alternative machinery be considered . . . (6.5).

38. External examinations to a very large extent control the nature of the work done in the schools. Since changes in school attitudes are most readily brought about by changes in examination procedure, we recommend that urgent attention should be paid to the nature and scope of examinations . . . (6.5).

Laboratory Accommodation, Equipment and Servicing (Chapter VII)

39. The amount of general laboratory assistance in the secondary schools of Wales is disturbingly small. We wish to make a strong recommendation that local education authorities should establish schemes for the employment and training of laboratory assistants and technicians . . . (7.4).

40. While much has been done in recent years to improve the science accommodation in the grammar schools of Wales, many secondary modern schools are still without laboratories adequately equipped and serviced. Also, when there are well-equipped laboratories, overcrowding in schools, due to unfore-

seen increases in numbers of pupils, sometimes prevents their proper use . . . (7.5).

41. In the planning and furnishing of laboratories, there should always be consultation, particularly at the early stages, between the architect and the teachers who will use the laboratories . . . (7.5).

42. Authorities should consider schemes which would allow schools freedom to buy their own science equipment, within annual cost limits. We consider that any advantages thought to accrue from the bulk buying of scientific apparatus and equipment do not outweigh the disadvantages of preventing the science teacher obtaining the specific apparatus he prefers (within this limited grant) . . . (7.5).

School Leavers (Chapter VIII)

43. While the total entry for the Ordinary level examinations has increased by 43 per cent in five years, the number who sat for four subjects or more has increased by only 25 per cent. Many pupils are entered who cannot achieve a significant result in terms of a group of subjects. The C.S.E. examination should be more suitable for these pupils . . . (8.2).

44. There are about 1,700 students a year, either in the sixth forms of schools in Wales or following G.C.E. Advanced level courses in colleges of further education, who find themselves at 18 years of age seeking employment. Many of these pupils would have been better advised to enter full-time or sandwich courses in engineering, applied science or business studies in a technical college . . . (8.5).

INSTITUTIONS OF HIGHER LEARNING

Training Colleges (Chapter IX)

45. Entrants should have passed in mathematics at the Ordinary level, as part of a balanced group of subjects including science, as soon as the supply situation warrants . . . (9.3).

46. Students being trained specifically for teaching science in secondary schools should take both physical science and biological science as main subjects . . . (9.4).

47. The present quota of places available for those students to be trained for teaching mathematics and science in secondary schools is wholly inadequate . . . (9.4).

48. The lack of adequate laboratory technical assistance is very serious . . . (9.6).

Technical Colleges (Chapter X)

49. The proportion of the age group following technical college courses is less in Wales than in England . . . (10.1).

50. The technical colleges in Wales are not producing enough technicians and craftsmen to enable the best value to be obtained from the technologists and applied scientists produced in the country should they remain in Wales as technologists; it is apparent that many technologists find employment outside Wales . . . (10.3).

51. General studies can assist in establishing the balance in education in technical colleges. There are difficulties of finding time in part-time courses but we strongly support all attempts being made to establish and develop these studies . . . (10.5).

52. There are serious problems arising from the low level of mathematics, science and English of some entrants . . . (10.2).

53. Research facilities must be improved if significant work is to be accomplished by those desiring and qualified to undertake research . . . (10.7).

54. There is a serious shortage of good laboratory assistants, but recruitment will depend on improvements in training, salary and promotion prospects . . . (10.8).

55. Recruitment of students for advanced full-time and sandwich courses is less than the facilities warrant . . . (10.9).

University of Wales (Chapter XI)

56. About one-third of the number who obtain an initial degree enter annually for courses leading to the Teacher's Diploma in Education. This proportion is satisfactory so far as numbers are concerned, when one considers the other strong demands for graduates, but it is a disturbing position for the schools that so few graduates with good honours degrees in mathematics and science are entering these courses . . . (11.5).

57. We welcome the movement in the University Departments of Education to pay greater attention to the practical aspects of the science teacher's work, but we are of the opinion that these aspects require greater emphasis . . .(11.5).

Adult Education (Chapter XII)

58. In order to develop scientific studies in extra-mural adult education, we recommend that there should be at least one full-time science tutor on the staff of each Extra-mural Department in the University of Wales . . . (12.2).

59. The University of Wales (through its Extra-mural Departments), the North and South Wales Districts of the W.E.A. and the local education authorities, should regard the expansion of facilities for science study for adults as a matter of urgency . . . (12.2).

60. Attention needs to be given by the organisations concerned to the training of part-time tutors in the most suitable methods of presenting scientific studies to adults . . . (12.2).

EDUCATION IN AN INDUSTRIAL SOCIETY

Demands of Industry and Research (Chapters II and XIII)

61. Wales is one of the most highly industrialised countries in the world but the emphasis in Welsh industry as a whole is still largely on the production side . . . (2.1; 13.1).

62. Although the Welsh industrial scene appears relatively healthy from the point of view of diversification and modernity, the position is, in fact, not entirely satisfactory. There are good reasons for thinking that there is a serious imbalance in Wales between the number of senior scientific and technological people and other employees engaged in industry. This, it would seem, can

only be remedied by the location of more design, development and research centres in industry in Wales and the employment of more managers with scientific and technological qualifications in industrial management. In comparison with the United Kingdom as a whole, Wales is sadly lacking in large research establishments, particularly in the physical sciences and engineering . . . (13.1).

63. The opportunities for graduates in Wales to follow a career in scientific or technical research are very limited and the facilities appear quite inadequate to satisfy the output of Welsh educational establishments. Urgent consideration should be given to the balance between scientific research workers and supporting technical staff in academic institutions and to the location in Wales of a government research establishment or establishments of significant size . . . (13.2).

64. Close contact between research centres and establishments of higher education is increasingly desirable from the point of view of modern scientific research . . . (2.1; 13.2).

65. The change-over to 'science-based' industries, as well as the more frequent transfer from one job to another, will demand a higher knowledge of basic science and greater adaptability from industrial workers. In order to meet this challenge, the schools will need adequate resources and good teachers . . .(1.3; 2.2).

66. There is an urgent need for a survey of scientists and technologists in Wales, particularly in relation to their employment and distribution within the Welsh industrial, administrative and academic scene . . . (13.2).

THE SUPPLY OF TEACHERS

67. In view of the increasing competition from industry, government research establishments and institutions of higher education, it is clear that the schools under present conditions have little prospect of recruiting a fair share of well-qualified graduates in science and mathematics within the foreseeable future . . . (XV).

68. It is necessary, therefore, to deploy as effectively as possible the best and most experienced teachers who are now in the schools, and also to give every assistance to those who are less experienced or well-qualified . . . (16.3).

69. Working conditions in the schools need to be improved, and of particular importance is the provision of well-equipped and serviced laboratories, together with adequate technical assistance. Apart from increasing the effectiveness of the actual teaching, improved working conditions would help to make the profession of teaching more attractive to the young scientist . . .(16.3).

70. Appropriately qualified teachers of science in schools should have opportunities to follow advanced courses or to do post graduate research work . . . (16.3).

71. Study should be made of the use of television and other audio-visual aids in the teaching of science and mathematics. Extensive use of aids may well help in the fuller deployment of the best teachers as well as helping others . . . (16.3).

72. A co-ordinated, sustained effort is needed to provide courses at the appropriate level and of suitable duration for practising teachers. We recom-

mend also that teachers should be able to attend such courses with no financial loss to themselves . . . (16.3).

73. At present, science and mathematics are often being taught by teachers with inappropriate qualifications in those subjects—for example, science taught by an arts graduate. Opportunities should be available for such teachers to work for an appropriate qualification. Consideration might be given to the establishment of a Diploma in Science parallel to the Diploma in Mathematics of the Mathematical Association. More teachers, who are not graduates in science or mathematics but who are teaching these subjects, would be encouraged to work for these Diplomas if all local education authorities granted day release to members of staff in their schools . . . (16.3).

74. In the difficult period ahead, every effort should be made to tap other possible sources, however small, of teachers of science and mathematics . . . (16.3).

75. There should be more opportunities for married women teachers to do part-time work . . . (16.3).

76. There is a case for the revision of the existing grants system applicable to the course of training in a university training department. The elimination of the means test might increase the numbers who undergo teacher training . . . (16.3).

77. The possibility of establishing a technical teacher training course in Wales should be explored, as a possible additional source of teachers of mathematics and science in the schools and technical colleges . . . (16.3).

78. A substantial number of pupils—about 1,700 a year—in the sixth forms of secondary schools in Wales are being lost to full-time higher education. Many of these, given the opportunity, might well make effective teachers of science and mathematics at the appropriate level . . . (16.3).

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APPENDIX I

Numbers of Candidates taking Science and Some Arts Subjects at the Advanced Level of the G.C.E.

Statistics provided by the Welsh Joint Education Committee.

1a: *Boys and Girls*

Subject	1951	1955	1959	1960	1961	1962	Nos. for 1962 as percentage of nos. for 1951
Physics	770	994	1,342	1,547	1,596	1,699	220·6
Chemistry	835	1,053	1,297	1,416	1,480	1,493	178·8
Botany	236	290	354	366	393	351	148·7
Biology	202	316	244	222	227	277	137·1
Zoology	258	306	449	503	560	597	208·1
Geology	52	96	155	149	185	225	432·6
English	997	959	1,112	1,201	1,246	1,493	149·7
History	698	765	812	919	975	1,209	173·2
French	555	530	543	542	612	732	131·9
Latin	249	302	257	284	285	279	112·5

1b: *Boys only*

Subject	1951	1955	1959	1960	1961	1962	Nos. for 1962 as percentage of nos. for 1951
Physics	688	824	1,152	1,324	1,317	1,390	202·0
Chemistry	671	808	1,055	1,127	1,144	1,135	169·1
Botany	112	157	201	197	197	177	158·0
Biology	139	198	151	152	142	167	120·1
Zoology	125	161	273	282	294	338	270·4
Geology	47	79	127	129	154	187	397·6
English	461	379	403	416	438	545	118·2
History	390	408	410	448	475	597	153·1
French	239	197	184	178	211	242	101·2
Latin	100	140	98	110	116	104	104·0

1c: *Girls only*

Subject	1951	1955	1959	1960	1961	1962	Nos. for 1962 as percentage of nos. for 1951
Physics	82	170	190	223	279	309	376·7
Chemistry	164	245	242	289	336	358	218·3
Botany	124	133	153	169	196	174	140·3
Biology	63	118	93	70	85	110	174·6
Zoology	133	145	176	221	266	259	187·2
Geology	5	17	28	20	31	38	760·0
English	536	580	709	785	808	948	176·8
History	308	357	402	471	500	612	198·7
French	316	333	359	364	401	490	155·1
Latin	149	162	159	174	169	175	117·5

APPENDIX II

Information Obtained from the Questionnaire on Staffing, 1961–62

Table 1 Summary of Qualifications of Teachers taking Mathematics and Science Subjects in Schools providing G.C.E. Courses

Subject		Higher Degree	Honours Degree					Pass Degree			Others					Professional Training		Total
			Class 1	Class 2A	Class 2B	Class 3	Total	Final	Subsid.	Total	G.C.E. 'A'	G.C.E. 'O'	Training College	Nil	Total	Trained	Untrained	
Mathematics		28	34	56	61	33	184	247	64	311	22	9	66	9	106	472	129	601
	%		(5·5)	(9·5)	(10)	(5·5)		(41)	(10·5)						(18)			(100)
Physics		14	17	41	45	25	128	93	15	108	8	2	3	4	17	209	44	253
	%		(6·5)	(16·5)	(18)	(10)		(36·5)	(6)						(17)			(100)
Chemistry		27	31	53	50	27	161	62	19	81	11	0	3	0	14	191	65	256
	%		(12)	(20·5)	(19·5)	(10·5)		(24)	(17·5)						(6)			(100)
Zoology		5	6	25	21	3	55	40	8	48	3	0	0	0	3	89	17	106
	%		(5·5)	(23·5)	(20)	(3)		(37·5)	(7·5)						(3)			(100)
Biology		11	15	45	45	10	115	66	4	70	2	1	11	7	21	167	39	206
	%		(7)	(22)	(22)	(5)		(32)	(2)						(10)			(100)
Botany		2	5	25	23	4	57	37	7	44	0	0	0	1	1	86	16	102
	%		(5)	(25)	(23)	(4)		(36)	(7)						(1)			(100)
General Science		10	10	32	42	22	106	90	1	91	4	1	20	0	25	178	44	222
	%		(4·5)	(14·5)	(19)	(10)		(40)							(11)			(100)
																		1,748

Notes:

(a) The figures in brackets represent the percentage of the total numbers.

(b) The information on which this table is based was obtained on a subject basis. In some schools one teacher is responsible for more than one subject. The actual number of teachers involved is 1,277 compared with the 'subject' total of 1,748.

(c) The 154 schools returning forms contained 84,675 pupils and employed a total of 4,272 members of staff.

APPENDIX II

Table 2 Distribution of Degree Qualifications of Teachers referred to in Table 1

Subject	Higher Degrees	Honours				Pass Degrees	Non-graduate
		1st	2a	2b	3rd		
Mathematics	5%	5·5%	9·5%	10%	5·5%	41%	28·5%
Physics	5·5%	6·5%	16·5%	18%	10%	36·5%	12·5%
Chemistry	10·5%	12%	20·5%	19·5%	10·5%	24%	13·5%

APPENDIX II

Table 3 *Qualifications of Heads of Departments concerned with Subjects in Table* 1

Subject		Ph.D	M.Sc.	M.A.	Hons. 1	Hons. 2a	Hons. 2b	Hons. 3	Pass	Non-graduates	Teaching Experience		
											0–5 yrs.	6–12 yrs.	Over 12 yrs.
Mathematics	%	0·6	3·7	1·2	16·0	21·8	21·8	9·0	27·6	3·8	10	24	66
Physics	%	1·5	6·5	0	12·5	27·0	17·0	12·0	28·0	3·5	27	23	50
Chemistry	%	2·5	13·0	2·0	21	28	20	11	19	1	18	23	59
Botany	%	1·5	1·5	0	6	27	20	3	35	9	15	30	55
Zoology	%	1	5	0	6	31	21	2·5	32	7·5	25	16	59
Biology	%	3	10	1	10	32·5	26	7	22·5	2	30	18	52
General Science			There were very few, and most in the 0–5 years experience category.										

Note:
Non-graduate here means no University degree in Mathematics or Science; the category includes those with Training College qualifications and G.C.E. Certificates at 'A' or 'O' level.

APPENDIX III

Qualifications of Teachers of Mathematics and Science in Secondary Modern Schools, 1961–62

Subject	Number of Teachers					Number of Schools with				
	Hons. Graduate	Pass Graduate	Supplementary One-year Course	G.C.E. 'A'	Lower or no qualifications	Hons. Graduate	Pass Graduate	Supplementary One-year Course	G.C.E. 'A'	Lower or no qualifications
1 Mathematics	7	31	26	55	115	7 (3·5%)	27 (13·5%)	25 (12·5%)	47 (23·5%)	115 (57%)
2 Physics	8	23	2	18	157	8 (4%)	22 (11%)	2 (1%)	18 (9%)	157 (78·5%)
3 Science (excluding Physics)	26	54	23	32	105	25 (22·5%)	46 (23%)	21 (10·5%)	30 (15%)	105 (52·5%)
Total (lines 1, 2 & 3)	41	108	51	105	377					
TOTAL	682					200				

APPENDIX IV

ANALYSIS OF SCHOOL LEAVERS

Table 1 *Wales: School Leavers during Year* 1963

A. Statistics provided by Department of Education and Science of School Leavers during Academic Year, 1962–63

(a) Number continuing education at:	
University and Colleges of Advanced Technology	1,720
Training Colleges for Teachers	1,470
Other Places of Further Education	3,340
(b) Young Persons entering employment	33,710

B. Statistics provided by the Ministry of Labour: Analysis of Industries entered by School Leavers in 1963

	Apprentices to Skilled Occupation	Employment Leading to Recognised Professional Qualifications	Entering Clerical Work	Employment with Training not Covered in Previous Cols.	Other Employment	Total
Agriculture, forestry, fishing	25	1	16	19	1,573	1,634
Mining and quarrying	281	3	83	1,105	79	1,551
Food, drink and tobacco	40	4	83	10	734	871
Chemical and allied Industries	70	10	53	7	70	210
Metal manufacture	283	21	236	191	310	1,041
Engineering, metal and electrical goods Shipbuilding and marine engineering	584	7	399	100	1,563	2,653
Vehicles	161	—	55	4	118	338
Textiles	57	4	62	116	304	543
Clothing and footwear	12	—	48	641	1,023	1,724
Other manufacturing industries	150	9	245	67	1,516	1,987
Construction	1,031	12	166	29	1,064	2,302
Gas, electricity and water	174	4	65	—	31	274
Transport and communication	136	18	184	52	247	637
Distributive trades	234	13	1,038	81	7,264	8,580
Professional, financial and miscellaneous services	1,068	297	1,554	182	2,487	5,588
Public administration	245	66	554	86	270	1,221
Totals	4,551	469	4,791	2,690	18,653	31,154

APPENDIX IV

Table 2 *Sixth Form Leavers* (1961–62)

(Information from the Statistics obtained from the replies to the Questionnaire on the Curriculum)

	Science				Arts				Mixed Arts and Science Subjects					
	Boys	%	Girls	%	Boys	%	Girls	%	Boys	%	Girls	%	TOTAL	%
1 Number of pupils in 1961–62 who attained minimum University entrance qualifications	1,150	38·2	339	11·3	681	22·7	736	24·5	58	1·9	42	1·4	3,006	100
2 Numbers of those who entered a University	662	22·0	207	6·9	344	11·4	345	11·5	25	0·8	13	0·4	1,596	53·1
3 Numbers of those who entered a Training College	31	1·0	32	1·0	87	2·9	194	6·5	7	0·2	18	0·6	369	12·3
4 Numbers of those who entered a Technical College	152	5·1	28	0·9	15	0·5	24	0·8	3	0·1	1	0·03	223	7·4
5 Numbers of those who entered Employment	79	2·6	25	0·8	98	3·3	96	3·2	7	0·2	8	0·2	313	10·4
6 Numbers of those who returned to school	228	7·6	54	1·8	159	5·3	70	2·3	13	0·4	6	0·2	530	17·0

Returns were received from 155 out of 159 forms sent out.
Some forms showed numerical errors; this explains the discrepancy between the total in the bottom line and the figures in line 1.

APPENDIX IV

Table 3 *Sixth Form Leavers: Comparison of Boys* (*b*) *with Girls* (*g*)
(Figures obtained from Table 2)

	(1) Total No. with at least minimum University Entry Qualification							(2) No. entering University						
Type of School	Science		Arts		Mixed		Total	Science		Arts		Mixed		Total
	b	g	b	g	b	g	b g	b	g	b	g	b	g	b g
Mixed	592	150	265	364	42	17	1,430	337	92	115	161	18	6	729
Boys	558		416		16		990	325		229		7		561
Girls		189		372		25	586		115		184		7	306
Total	1,150	339	681	736	58	42	3,006	662	207	344	345	25	13	1,596

APPENDIX IV

Table 4 Pattern of Sixth Form Work in Mathematics and Science, 1962–63

(Information obtained from the replies to the Questionnaire on the Curriculum)

	No. of pupils in Sixth Form		No. taking 3 'A' levels		No. taking P. Maths, A. Maths, Physics		No. taking Chemistry, Physics, Maths.		No. taking Chemistry, Physics, and Biology or Zoology		No. taking Botany, Zoology and another Science		Total No. of 2nd year students			Total No. of Third Year Students taking 3 'A' levels	
	2nd Year	3rd Year	2nd Year	3rd Year	2nd Year	3rd Year	2nd Year	3rd Year	2nd Year	3rd Year	2nd Year	3rd Year	General	Others 3 A	Science 3 A	Others	Science
	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g	b g
Boys Girls Total	2,018 1,659 3,677	591 179 770	1,741 1,181 2,922	518 142 660	250 71 321	83 18 101	562 83 645	119 7 126	217 128 345	78 32 110	136 127 263	45 14 59	277 478 755	576 762 1,338	1,165 419 1,584	193 71 264	325 71 396
Percentage of total No. in Sixth (3677=100%) Boys Girls Total	54·9 45·1 100	16·1 4·9 21·0	47·4 32·1 79·5		6·8 1·9 8·7		15·3 2·3 17·6		5·9 3·5 9·4		3·7 3·5 7·2		7·5 13·0 20·5	15·7 20·7 36·4	31·7 11·1 43·1	5·3 1·9 7·2	8·9 1·9 10·8
Percentage of No. taking 3 'A' levels (2,922 = 100%) Boys Girls Total			59·6 40·4 100		11·0		22·1		11·8		9·0			45·8	54·2		

APPENDIX IV

Table 5 Numbers of Pupils in Maintained Secondary Schools in Wales
(Ministry of Education, Annual Reports and Statistics of Education)

(a) *Total Number of Pupils*

Year	Modern*	Grammar*	Technical	Comprehensive†	Other	Total
1958	71,603	55,604	3,601	13,165	1,093	145,066
1959	81,129	57,307	3,779	15,533	522	158,270
1960	85,519	59,853	2,877	17,514	550	166,313
1961	92,811	61,665	2,180	19,053	584	176,293
1962	91,448	62,315	1,737	22,337	558	178,395
1963	84,988	58,886	1,537	29,835	331	175,577

* Includes pupils from bilateral and multilateral schools except in 1963.
† In 1963 includes bilateral and multilateral school pupils.

(b) *Distribution of School Leavers from Various Types of Schools*

Year	Modern	Grammar	Technical	Comprehensive	Other	Total
1958	19,263	8,247	834	3,392	232	32,148
1959	20,590	8,786	1,045	3,871	125	34,417
1960	20,308	9,518	871	4,111	399	35,207
1961	22,670	9,160	539	3,304	252	35,925
1963	23,650	9,570	560	3,450	270	37,500

(c) *Age on Leaving School*

	at 15		15+		16+		17+		18+		19+	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
1958	1,991	1,879	9,958	9,185	1,965	1,887	1,050	1,131	1,104	1,215	619	164
1959	1,966	1,923	10,564	9,780	2,175	2,235	1,158	1,256	1,214	1,297	680	169
1960	7,939	7,489	4,456	3,918	2,455	2,388	1,407	1,411	1,384	1,463	719	178
1963	9,280	9,510	4,210	3,130	3,250	2,870	1,450	1,950	1,480	1,740	1,100	280

APPENDIX IV

Table 6 Numbers of Pupils Entering and Passing at 'O' and 'A' Level of the G.C.E.

Year		1958	1959	1960	1961	1962	1963
'O' Level Entry		14,316	17,014	17,922	18,622	20,473	23,490
Entry for four or more subjects		9,825	10,711	11,406	11,457	12,311	14,399
Pupils passing in four or more subjects	Total	5,927	6,460	6,759	6,730	7,271	8,564
	Boys	2,852	3,134	3,276	3,160	3,550	4,278
	Girls	3,075	3,326	3,483	3,570	3,721	4,286
'A' Level Entry	Total	3,755	4,134	4,452	4,704	5,526	5,339
	Boys	2,328	2,576	2,758	2,845	3,154	3,172
	Girls	1,427	1,558	1,694	1,859	2,072	2,167
Passes in one subject	Total	955	1,048	1,135	1,265	1,269	1,319
	Boys	532	612	657	667	737	737
	Girls	423	436	478	598	532	582
Passes in two subjects	Total	991	1,008	1,040	1,017	1,260	1,228
	Boys	542	589	618	645	724	687
	Girls	449	419	422	372	536	541
Passes in three or more subjects	Total	1,186	1,275	1,432	1,921	1,713	1,173
	Boys	810	872	958	968	1,100	1,130
	Girls	376	403	474	453	613	643

APPENDIX V

Numbers of Candidates in Certain Subjects in the Final Examination for the Teachers' Certificate

(University of Wales, School of Education)

Year	Total No. of Students	Mathematics	Physical Sciences	Biological Sciences	History	Geography	Physical Education	Handicrafts (men)	Music	English	Welsh
1956	720	26	2	75	78	86	69	20	35	87	99
1957	743	31	6	66	85	82	65	22	37	69	103
1958	758	39	4	70	89	88	92	22	37	75	96
1959	866	59	21	66	99	115	110	16	49	90	97
1960	869	54	5	84	99	108	122	25	44	96	98
1961	974	69	7	78	101	140	131	21	42	99	93
1962	Year of intermission—no 3 year trained students qualifying										
1963		88 (22)	39	99 (12)	126 (16)	166 (29)	176 (52)	26 (15)	56 (12)	148 (24)	107 (32)

Notes: (a) The figures in brackets refer to students taking Advanced Main level.

(b) Contrary to the practice in previous years, from 1963 students were able to take two Main or one Main and one Advanced Main subject. This in part accounts for the apparent large increase in students taking the examination.

APPENDIX VI

Proportional Analysis of Results of the 1961 Census of Scientific and Technical Qualifications

	Wales	Great Britain	Scientific & Technically Qualified (Great Britain)	Population Proportion for Wales
Total Population	2,620,000	50,578,000	287,610	14,800
Total Employed	970,000	22,490,000	247,970	10,650
Agriculture, Forestry and Fishing	23,400	599,000	4,720	177
Mining and Quarrying	107,500	737,000	4,200	610
Food, Drink and Tobacco	21,500	813,000	3,380	89
Chemical and Allied Industries	25,000	534,000	19,480	910
Metal Manufacture	91,700	637,000	6,470	930
Engineering and Electrical Goods	49,300	213,300	38,310	885
Shipbuilding and Marine Engineering	5,400	252,000	1,650	35
Vehicles	17,500	894,000	13,340	261
Metal Goods not elsewhere specified	23,000	563,000	2,460	101
Textiles	17,000	844,000	3,890	79
Leather, leather goods and fur	2,100	63,000	100	3
Clothing and Footwear	14,200	573,000	240	6
Bricks, Pottery, Glass, Cement etc.	10,500	347,000	2,160	65
Timber, Furniture etc.	6,300	290,000	340	7
Paper, Printing and Publishing	10,500	616,000	1,900	32
Other Manufacturing Industries	12,000	308,000	2,300	90
Construction	80,500	1,511,000	9,270	495
Gas, Electricity and Water	19,900	382,000	12,280	640
Transport and Communication	79,900	1,658,000	5,290	255
Distributive Trades	104,300	2,829,000	4,680	172
Insurance, Banking and Finance	8,400	560,000	2,480	37
Professional and Scientific Services	30,000	2,059,000	82,350	1,200
Miscellaneous Services	30,300	2,008,000	6,690	101
Public Administration and Defence	49,200	1,278,000	19,130	738
				7,918

APPENDIX VII

Some Notes on the Educational Systems of Other Countries*

I. *The Educational Pattern in France and Western Germany*

In both countries a school starting age of six is followed by a period of primary education in state schools (although a small minority of pupils attend voluntary schools) leading to a fairly complicated pattern of secondary education for which selection takes place between the ages of 11 and 13. The selection of the more able pupils for the French Lycée or the German Gymnasium generally takes place at 11. Selection procedures in France are based on the ability of the pupil, as assessed by school records, and the wishes of the parent during a two-year 'cycle of observation' between 11 and 13 years of age, although an examination is used as the final judgement in case of doubt. In Germany much use is made of vocational guidance tests and talks with parents and pupils to assess their suitability for the various kinds of secondary schools.

Secondary education in both countries is either 'long' or 'short', the former being designed for able pupils who will stay in school until 18 or 19 years of age before entering the university or institutions of higher technical education. The 'short' education comprises vocationally biased courses which end at 17 in France and 18 in Germany. Although attempts are made to keep the curriculum broad by the addition of general studies to vocational work, both countries encourage pupils to embark on strongly biased vocational courses from a much earlier age than is common in Britain. Pupils are thus required to decide on their future careers at 13 to 14 years of age by entering courses leading, for example, to mechanical engineering, or chemical plant operation, in a 'collège d'enseignement technique' in France or in the 'Berufsschule' of Germany.

The able pupils in the Lycée or Gymnasium choose various kinds of courses from quite an early age, for example, classical, modern, scientific, mathematical. Sometimes these involve attending separate establishments, for example, the 'Lycée Technique' in France or the 'classical' Gymnasium in Germany. There appears to be a growing tendency to provide the different courses in the same establishment, leading, in France, to the concept of 'l'ecole polyvalent' where all forms of secondary education, including the highly specialised vocational courses, are provided in the same establishment under one director. This would correspond to the British comprehensive school to which the local college of further education had been added. In all the courses leading, in the Lycée or Gymnasium, to the 'Baccalauréat' in France and the 'Abitur' in Germany, the early years comprise a common foundation of broad studies, with emphasis on the pupils' own language and at least one, but generally two, foreign languages.

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* These notes are based on information obtained from published documents of O.E.E.C., U.N.E.S.C.O., the Iron and Steel Industry and a variety of other sources

Mathematics is taught thoughout, except that a few pupils, for example, in classical courses in the last year, are allowed to drop the subject. The pace seems to be generally slower than in British schools judged by the content of syllabuses. Less ground is covered in the early years but more attention is paid to applications of knowledge and thoroughness of understanding. The subject is studied for a longer period, however, and pupils leaving school at 18 or 19 have a knowledge of mathematics higher than that required for the G.C.E. Ordinary level. In France material is included which is quite outside even Advanced level syllabuses in Britain, such as statistics and elementary probability theory. The separate subject 'Applied Mathematics' is unknown but aspects of kinematics and astronomy are included in the mathematics syllabus.

Science in the early years consists mainly of biology. Physics is started in the third or fourth year and chemistry a year later. The time devoted to science does not differ greatly in the various kinds of courses; only in the later years is there any difference. The total time is, however, much less than that given in British schools to pupils who have opted for science subjects in preference to others. In the schools of both countries much less attention is paid to practical work in science, but this is recognised as a weakness which is being rectified as quickly as possible.

It is interesting to note that the subject options of British schools do not appear to exist. Pupils select courses in which the subjects and time allocations are fixed.

Part-time education plays only a minor part in the French system. Day-release from work is very exceptional and most pupils receive further education for skilled work either in the full-time state schools—the old apprenticeship centres, now the 'collèges d'enseignement technique'—or in corresponding establishments run by industry. There is a levy on industry for industrial training from which firms can contract out by making their own provision. There is keen competition to enter and many students are unable to get places. Workers in industry can take the same examinations as those taken by full-time students if they attend evening classes in their own time. These are provided mainly in Paris and urban areas, and students attend for three or four evenings a week and on Saturday or Sunday for practical work. They get no direct financial benefit from attending these courses but the 'qualified' worker enjoys great esteem among his fellow workers and self-respect demands in the case of most workers that they should be able to regard themselves as 'skilled', for which possession of the appropriate qualification ('Certificat d'aptitude professionnelle'—C.A.P.) is necessary.

In Germany education up to the age of 18 is compulsory for all, but in the case of many students who leave school at 14 or 15 to enter industry, this takes the form of part-time education in the 'Berufsschule', where a wide variety of vocational courses is provided.

Both countries make strenuous efforts to match vocational education to the needs of industry; the impression is left, particularly in France, that industry states its needs, in terms of numbers of people required at various levels and the kind of training needed, very precisely. Every effort is made by the government to satisfy these requirements, but the scale of provision in France is not yet adequate to meet the needs of a rapidly expanding economy. In Germany the scale of provision accords more closely with the present requirements.

France and Germany, in their respective full-time and part-time training systems, pay very much more attention to the training of technicians than is done in Britain. The role of a technician in industry seems better appreciated and the work enjoys greater public esteem. In France many pupils with possession of the 'Baccalauréat', instead of entering a university, choose to enter a full-time course leading to higher technical qualifications. These are 'Brevet d'agent technique' (B.A.T.) after two years or 'Brevet de Technicien (B.T.) after three years. These courses are provided in the 'lycée technique' or 'collège d'enseignement technique' or in special establishments and are available in a wide range of technologies, including aspects of business studies and hotel and catering trades. The courses are also available to skilled workers who have obtained their C.A.P. but the competition to enter the courses is very severe and most students have passed their 'Baccalauréat'. In Germany the Fachschule offers similar full-time technician courses in addition to the part-time courses of the Berufsschule.

The top level personnel in industry are generally trained in special 'Engineer' Schools or Advanced Technical Institutions, although a few enter from the universities. The latter are generally regarded with less esteem and occupy less important posts.

In France pupils who wish to enter a 'Grande École' to take the 'Diplôme d'Ingénieur' stay on in school for two years after the Baccalauréat studying mainly mathematics and science but with at least one foreign language and other subjects of general education. The standard of work in mathematics is very high, going well beyond the G.C.E. Advanced level. In science it is of approximately Advanced level standard but different in content, with more emphasis on mathematical applications and less on experimental work. Some of the 'Grandes Écoles' admit only one in ten of the applicants and, since it is very difficult to get a place, students sit the entrance examinations of more than one establishment. The unsuccessful enter a university where there is no difficulty in getting a place, but there is a very high wastage rate at the end of the first year.

In Germany there is not such a great gap between the technical institutions and universities, but some of the advanced technical institutions are of world wide standing for the quality of their teaching and scholarship. Their graduates are held in high esteem by industry.

II. *The United States of America*

The educational system of the United States differs completely from those considered above. The organisation of the schools is the direct concern of the individual states with the Federal Government playing little direct part in the process. The great diversity to be found throughout the country is further increased by the fact that schools are run by School Boards, some of which are very small and control only a limited number of schools. This independence from central authority is thought to be very important and is jealously guarded.

The body which corresponds to the Ministry of Education in England and Wales and other European Countries is the Federal Office of Health, Education and Welfare, although its functions are much more limited. It collects and disseminates information and on request it can act as consultant to state organisations. It is not an executive body. Education is a function reserved to individual states under the constitution and any suggestion of encroachment on their independence is viewed with disapproval. There is not in American education any body whose writ runs throughout the country. Neither are there any bodies corresponding to our Central Advisory Councils or Royal Commissions which offer advice on a nation wide scale.

There is, however, widespread concern at some of the apparent failures of the educational system. Reform is the order of the day, particularly in science and mathematics, and much of the momentum for the current movement stems from the Russian achievements in space, starting from the first 'Sputnik'. Many Americans appear to be alarmed about the state of their science teaching and are doing their utmost to effect changes rapidly.

The National Defence Act of 1958 contained educational provisions authorising the Office of Health, Education and Welfare to spend money on scientific education:

(a) by the appointment of advisory staff at the state level,
(b) the provision of 50 per cent grant for the minor remodelling of buildings.
(c) the purchase of scientific equipment and the development of new teaching aids,
(d) research into the effectiveness of new media of instruction, and
(e) the organisation of regional conferences of teachers.

Another national body spending even larger sums for the promotion of science teaching is the National Science Foundation, which operates under the National Science Foundation Act of 1950. It is an entirely separate organisation for dispensing Federal money and can be compared in some aspects with the Department of Scientific and Industrial Research in Britain. Besides research it has a large programme for education and science; its money is made available for the latter purpose as follows:

(a) the endowment of Fellowships,
(b) to establish Institutes whose main purpose is to organise refresher courses for teachers who receive payment for attendance,
(c) the development of special projects for improving instruction in science, mathematics and engineering, particularly to increase the understanding of these subjects by young people,
(d) to give support to projects designed to produce up-to-date material for course content,
(e) to establish a scientific man-power programme dealing with scientific personnel.

In all these activities the National Science Foundation acts purely as a sponsoring body and any discrimination it exerts is done by estimating the responsibility of the person or group of persons wishing to explore a problem. It has not itself attempted to assess the value of any work but has been prepared to support any proposals put forward by responsible people. In practice, this support has gone almost exclusively to groups from the universities or of a research character. There have been no guiding principles and each group has formulated its own policy. The educators have felt themselves to be left out of the picture to some extent.

A third body which operates on the national scale is the National Education Association which includes the National Science Teachers Association. The latter body has exerted considerable influence in the years between the two wars, but does not at present choose to compete with the activities of the National Science Foundation.

Education in the United States begins at about the age of six in Grade I or one year earlier in the Kindergarten. It is organised in yearly grades, ending in Grade 12 which leads to college and from which pupils graduate from their High Schools. There are various arrangements of the grades within different types of schools. In urban areas the first six grades are generally located in Elementary Schools, followed by three in a Junior High School and Grades 10, 11 and 12 in a Senior High School. In rural areas the last six grades are sometimes joined together within a six-year High School, but more often Grade 9 is part of a four-year High School and the Elementary School includes Grade 8. Most schools are comprehensive in character and cater for all the pupils in the areas they serve; they contain two to three thousand pupils. A few, such as the Bronx High School in New York City and the Boston Latin School, are selective and admit only able pupils. In country districts the schools are generally too small to cater adequately for the needs of both the ablest and least able pupils.

To graduate from High School a student must collect a specified number of 'units' which are awarded for the satisfactory completion of a year's course in a specified subject; it is the function of the State Board to determine the number of 'units' needed to qualify for a High School Diploma, some of them in 'required' subjects while others are optional. In a typical comprehensive High School a total of 32 major subjects is required, 24 of which must be passed in the last three grades. Required major subjects are: English (4 years), world geography (1 year), modern history (1 year), American history (1 year), economics (½ year), health training (1 year), general science (1 year) and mathematics (1 year), although the time devoted to the latter subjects may be increased if they form part of a 'Sequence'. Required minor subjects are art appreciation, health education, hygiene, driver education and 'Required Music'. Other subjects are selective but all pupils must pass a three year 'Sequence' in one subject area, for example, mathematics or the sciences and one or two two-year sequences in single subjects, depending upon the type of diploma. Attempts to correlate the results from different schools are not very successful; even more difficult is it to assess standards within each particular subject. For entry purposes the colleges are tending to rely increasingly on examinations set and assessed by the College Entrance Board.

Courses are arranged in yearly units for five periods a week (that is, one per day). The day normally consists of seven periods and the time-table of a teacher or pupils is, as a rule, the same for every day of the week. This system, which has evolved to allow a wide range of alternative courses, makes time-tabling easy, but has some serious disadvantages. It is difficult to give a subject more or less than five periods a week and to arrange double periods for practical work in science. It has also led to the science course being arranged in 'layers' with one branch in each year of the course. Although there are many variations the most frequent arrangement is for general science to be included in Grade 9, biology in Grade 10, chemistry in Grade 11 and physics in Grade 12. It is thus impossible for topics within a given branch to be taken at a time when they match the pupils' maturity and for the various branches of science to be adequately correlated with each other. There are frequent arguments as to which subjects should come first, but such discussions do not touch the core of the difficulty. In some schools the sequence has been pushed forward recently to Grade 8, thus allowing another year in Grade 12 for more advanced work, generally taken in one subject. These courses are so designed that they give exemption from the first year of college work in that subject.

Progress in science appears to be often limited by lack of attainment in mathematics. Age for age, American students are said to be behind their

European counterparts. The calculus is rarely studied soon enough to be useful in High School science; it seems to be taken for granted that the subject can only exceptionally be taught in High School. There is at present a great deal of activity taking place concerning the teaching of mathematics and great hopes are centred on the reform of the mathematical curriculum. Most of the changes, however, are based on the theory of sets and other abstractions and it is doubtful if this approach will best serve the needs of science.

The present concern over the teaching of science followed from the recognition that standards were falling and science courses were being taken by proportionately fewer students. Some figures provided by the National Science Foundation show that 67 per cent of pupils in Grade 9 were studying general science, 76 per cent of those in Grade 10 were studying biology, 35 per cent of those in Grade 11 chemistry and 24 per cent of those in Grade 12 physics. Thus nearly two-thirds of American pupils will have studied no physical science by the time they leave High School at 18 years of age. This is reflected in the provision of laboratories, which is meagre in many schools and generally much less generous than in comparable schools in England. Practical work, as it is known in this country, plays only a minor part in American science teaching; double periods for it are rare. Even demonstration experiments are not common; science workshops and laboratory assistants are rarely found in American High Schools. Much time is spent in the physical sciences in working out numerical exercises. The amount of science included in the curriculum is also reflected by the proportion of staff teaching the subject; only about one teacher in 12 in a High School is teaching science; which contrasts markedly with the figure of about one in five for Welsh grammar schools and is much more like the position in the secondary modern schools in Wales discussed in Chapter VII. It is only in a few highly selective schools that the proportion reaches one to five as in the grammar schools of this country.

It is not surprising that the crash programme necessary to bring the teaching of science and mathematics in the High Schools up to the best European standards has produced many suggestions and experiments in the use of new techniques. 'Team teaching' is gaining ground in many schools. For this, classes are grouped together to form large audiences to see lecture experiments and to make the best use of the limited number of qualified teachers available. New school buildings are being designed to allow this to be done, by the inclusion of very large lecture rooms in science departments. Experiments with closed circuit television and the transmission of special science programmes on television are refinements of this technique of reaching a large number of students with a limited number of teachers. Teaching machines, too, which originated in the United States of America are being tried extensively, particularly in the teaching of mathematics. The scale of some of these experiments is shown by the Washington County experiment in which 130 miles of coaxial cable link up 50 schools in the county in which 16,000 pupils are educated. A permanent staff of 27 teachers broadcast some 122 lessons 'live' each week. Sets are provided in the schools on a basis of one to every 25 pupils. Much of the equipment was supplied by firms interested in developing a market for their equipment. The transmitting state and studio are manned by students from a local college who are intending to make their careers in this field. The value of the equipment is about 390,000 dollars. The experimental transmission 'Continental Classroom' at 6.30 a.m. broadcasts lessons of senior high school or college level and is viewed by about a quarter of a million people. The recent introduction of 'Dawn University' by East Anglia T.V. company follows a similar pattern in England. Films, too, are being made available from a variety of sources and experiments are also taking place in the supply of packaged equipment with detailed instructions for its use, intended for use by teachers with little or no previous experience of science teaching.

The most interesting of all the American experiments, however, is that concerned with the content of syllabuses. These consist of four groups of people operating with funds from the National Science Foundation. The Physical Sciences Study Committee is centred on the Massachussetts Institute of Technology; the Chemical Bond Approach Committee is based on two or three universities in the east; the Chemical Educational Materials Study Group works at the University of California; the Biological Sciences Curriculum Studies Group is working at the University of Colorado. Each of these committees is working on the reform of the curriculum within the pattern of organisation as it exists in American High Schools today. None of them has considered it within its competence to consider any possible changes in the structure of the school curriculum. Each is engaged upon the preparation of a new course of one year's duration in its own particular branch. It is consequently assumed that each of the main branches of science will be studied in the present order—general science, biology, chemistry, physics—and that each will be studied independently of the others. It is further assumed that practical work will be limited by the demands of the time-table to 50 minute periods and that the mathematical knowledge of pupils must remain at a very modest level. The experiments are being pursued with great thoroughness, including testing in a large number of schools and many conferences with teachers. It is estimated that its new course in physics will have cost five million dollars by the time it is finished.

III. *The U.S.S.R.*

The distinctive feature of the Soviet system is the strong central direction. There is a plan known to everyone, displayed diagrammatically on public hoardings and given meaning as yearly targets are visibly met. With state ownership and control over the supply of money and materials, planning can be carried out precisely. Through careful streaming of education and training and by relating pay to education 'grades', each branch of the economy receives, more or less exactly, the intended quota of recruits.

Whilst in theory each of the 15 separate Republics, with their own Ministries of Education, has full legislative powers over general school education, in practice, all schools, together with time-tables, curricula, text books, teaching methods and standards, are controlled by the Ministry of Education in Moscow. For higher and specialised secondary education there is one central ministry only.

Compulsory full-time education begins at seven and like the French system can be regarded as 'long' or 'short'. The seven year compulsory 'incomplete secondary education' and the 10 year 'complete secondary education' have both recently been increased by one year. Since 1958 there has been increased emphasis on practical work in factories, mines, farms, buildings, or public services as an essential ingredient of *all* secondary education. With certain exceptions students may not enter higher education until they have both worked for 18 months to two years in an office, farm or factory and obtained a completed certificate of secondary education. The exceptions are those with special talents and include future mathematicians, physicists, and those pupils with special aptitudes in art, music and ballet. At the age of 15 or 16 about half the pupils leave the main stream of secondary education for vocational technical schools which are directly associated with a particular industry rather like the French apprenticeship centres run by individual firms. About half of all the pupils in the vocational schools also attend evening classes.

School classes are unstreamed but promotion each year depends on a pass mark and not on the age of a pupil. Children are expected to do a considerable amount of homework, and at the same time assist in cleaning their own classrooms, laboratories and workshops for which they are awarded merit marks. Such marks are also awarded for participation in school clubs, for good behaviour and general tidiness. All privileges depend on good marks and there is intense competition among pupils to have their names on 'merit boards' prominently displayed within the school. The system ensures hard work. The education grade on a six point scale determines admission to higher education and recruitment to all forms of employment.

The education in all the technical schools and higher establishments is free and there are state grants to students which are, however, sufficient for only the most frugal existence. Entry to courses is strictly competitive and by selection; the numbers are controlled to meet planned needs. Differential grants between institutes of higher education and even between subjects are used to control the flow. Mathematicians receive 50 per cent more than the basic grant; this does not appear to be regarded as unfair by other students.

Only one-sixth of higher education is provided in universities and in these one half are graduates in mathematics or science. Separate specialised institutes provide training in major technologies such as medicine, agriculture and architecture. An increasing number of polytechnics provide high level courses in a range of technologies such as metallurgy, building, and branches of engineering. There is a severe shortage of places for the students who wish to take advantage of them.

There is extensive use of part-time, evening and correspondence courses. Only half of all higher education students are full-time; of the rest about three-quarters study through correspondence courses and the remainder through evening study. Correspondence courses are run by an institute which the students attend full-time for four weeks in the year for practical work.

APPENDIX VIII

LIST OF PERSONS AND ORGANISATIONS WHO SUBMITTED EVIDENCE

The Following Gave Oral Evidence

Professor Sanborn C. Brown	Massachussetts Institute of Technology, U.S.A.
Mr N. Clarke	Deputy Secretary, Institute of Physics and Physical Society
Mr J. Cotterell	Principal, Llandaff Technical College.
Dr A. Harvey	Principal, Welsh College of Advanced Technology, Cardiff.
Mr T. M. Hodges	Welsh College of Advanced Technology.
Dr C. S. Lyons	Principal, Flintshire Technical College
Mr A. J. Nicholas, C.B.E.	Chairman, South Wales Switchgear, Ltd.
Sir Julian Pode, J.P.	Chairman, Steel Company of Wales; President, British Iron and Steel Federation.
Mr H. B. Putt	Secretary, University of Wales Appointments Board.
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Secretary	South Wales Electricity Board.
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Welsh Secondary Schools Association.
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Association for Science Education.
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Association of Teachers in Technical Institutions.
Welsh Joint Education Committee.
University of Wales—School of Education.
University of Wales—Registrar.
University College of Aberystwyth—Department of Education.
University College of Aberystwyth—Faculty of Science.
University College of Aberystwyth—Registrar.
University College of North Wales, Bangor—Department of Education.
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PART I THE REMIT: INTERPRETATION

DEPARTMENT OF EDUCATION AND SCIENCE

CENTRAL ADVISORY COUNCIL
FOR EDUCATION (WALES)

Science in Education in Wales Today

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Foreword

This Report was presented to the Right Hon. Sir Edward Boyle, Bt., M.P., then Minister of Education, in March 1964. In addition to examining the vital place which science and mathematics must occupy in a balanced system of education in a modern society, the Central Advisory Council for Education (Wales) has performed a valuable service in reminding us of the dangers of too early specialisation in schools, and in suggesting ways in which these subjects can be more effectively taught at all stages. The Council is rightly concerned about the situation which exists as a result of the shortage of well-qualified teachers of science and mathematics and the effects of this shortage on the future supply of scientists and technologists for industry and research. It offers advice on ways of awakening and sustaining interest in these subjects and of making it possible for highly qualified teachers to be given adequate assistance in laboratory work.

Dear Minister,

In April, 1961, *your predecessor, Lord Eccles, invited the Central Advisory Council for Education (Wales) to undertake an enquiry into the place of mathematics and science in a balanced educational system for Wales.*

I have great pleasure in submitting our Report.

Yours sincerely,
Frank Llewellyn-Jones
(*Chairman*)

The Rt. Hon. Sir Edward C. G. Boyle, Bart., M.P., Minister of Education.

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Terms of Reference

To consider the place of mathematics and science in a balanced educational system for Wales.

* Resigned July, 1962. ** Resigned April, 1962 † Appointed July, 1962

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